Building and Construction

Carry out setting out

Learner Guide

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Setting Out [1]

Construction Processes

Main steps in the construction phase include (for typical slab & brick construction):

1. **Site preparation** This involves clearing of the site and pegging out of the site by the surveyor. Sometimes retaining walls will also be built at this stage if required.
2. **Slab** The plumber will need to lay plumbing that will be located beneath the slab of the development. This needs to be done before the slab can be formed up. The slab piering is then completed as per the engineer's specifications and plans and then the slab can be poured. It's very exciting to see the slabs go down.
3. **Frames and roof trusses** The frames are generally prepared before being delivered to site and can be erected very quickly with a day or so. It's great to walk around the site once the frames are up and get a feel for each room.
4. **Roof tiling of metal roofing** Some builders prefer to complete the roof before starting the brickwork and other builders work the other way around. I've found predominately builders want to get the roof on as quickly as possible to protect the frames.
5. **Brick work** This stage really gives the development true structure, and you can feel the development making good progress when you see the brickwork completed.
6. **Rough ins** This involves the electrical and plumbing wiring and pipes to be installed before the internal linings to the frames.
7. **Internal linings** After the rough in is complete, the insulation will be installed into the wall and ceilings and then the plaster will start on lining the walls and ceilings. You really get a good sense of space within the dwellings at this stage.
8. **Waterproofing and tiling** The wet areas will be water-proofed in preparation for the tilers to start work, generally after or even during the timber mould out.
9. **Timber mould out** This stage involves the carpenters installing the skirting boards, architraves, door jams and doors and kitchens.
10. **Lock up** is when all external doors including garage doors are on.
11. **P.C. fit out.** P.C. is a term for a prime cost item and includes tapware, bath, mirror, vanities and other accessories, which are installed at this stage.
12. **Practical completion.** This is the point in time when an inspection is conducted when builder is almost finished. You will walk through the development with the site manager and point out any items that still need attention. By this time it should only be touch ups and minor items requiring installation.
13. **Handover** This is when you are happy the construction has been completed to your satisfaction and to the plans and after paying the builder's final invoice, keys will be handed over to you.

[1] Source: Property Observer, as at http://www.propertyobserver.com.au/g,, as on 18th February, 2014; Paving Expert, as at http://www.pavingexpert.com/setout01.htm, as on 18th February, 2014; Home Design Directory, as at http://www.homedesigndirectory.com.au/house-construction-articles.php, as on 18th February, 2014; Builder Bill, as at http://www.builderbill-diy-help.com/setting-out.html, as on 19th February, 2014; BuildEasy, as at http://www.buildeazy.com/plans/helpfiles_profile.html, as on 19th February, 2014.

Legal Requirements & Documentation

Why do we have plans?

- Plans show all people interested in the proposed structure what it will look like when completed, and how it will be constructed.

People who may have an interest in plans for proposed structures:

- the client and the lending body
- local council (they must approve the application before the project can proceed)
- various supply authorities, for example, water, sewerage and drainage
- electrical and gas and cable supply companies
- builders and sub-contractors wanting to quote on the project
- the client and the lending body
- engineers
- carpenters
- bricklayers
- concreters
- painters (dry wall & wet wall plasterers)
- real estate agents
- neighbours
- kitchen manufacturers
- landscapers
- various material or product suppliers
- e.g. windows & doors, timber etc
- environmental agencies
- mechanical service installers, e.g. air conditioning, fire alarms
- may also have an interest
- excavation contractors plasterers (gyprockers)
- surveyors
- electricians
- roof & floor tilers
- plumbers
- form workers
- police, fire brigade
- bathroom and mirror suppliers
- roads & traffic authority

What will the plans show the interested parties?

They will:

- show the location of various features on the site and illustrate details about the building e.g. construction details for specific trades people
- show the height, position and bulk of the building so that council can determine compliance to its codes.

- allow builders and trades people to prepare written quotations. Remember written quotations (quotes) or contracts should only relate to approved building plans. An estimate should be given prior to council approval.
- provide the surveyor with the details for setting out
- illustrate to trades people the structure to be built.

Once your house design has been finalised and a preliminary costing-estimate has been completed it is time to lodge your plans into council.

DA (Development Application)

A DA (Development Application) is the first part of the council approval process. The DA is typically submitted by the developer or owner to the local council for approval of new homes and renovations that involve structural changes. Design drawings, Statement of Environmental Effects, Materials Reuse Statement (also called a Waste Management Report) and a BASIX Certificates (or equivalent, depending on your state) must accompany the application. Other reports such as Flora and Fauna Assessments, Bushfire Assessments and Geo-technical Assessments may also be required (you need to check with your local council). Together these documents describe the usage, style, size and location of the intended building and its surrounds including the zoning and any special conditions that may be placed upon the property.

Those special conditions or encumbrances are listed in the Section 149 Certificate that form part of the contract of sale document. They can include:

- bushfire areas
- earthquake of subsistence areas
- alpine environments
- waterways
- heritage
- flood zone

These encumbrances can limit your choose of construction types eg, rendered brick walls are not suggested in mine subsidence areas due to the cracking that will most likey occur as a result of ground movement. For the same reasons, unusual structures such as strawbale buildings will need special consideration.

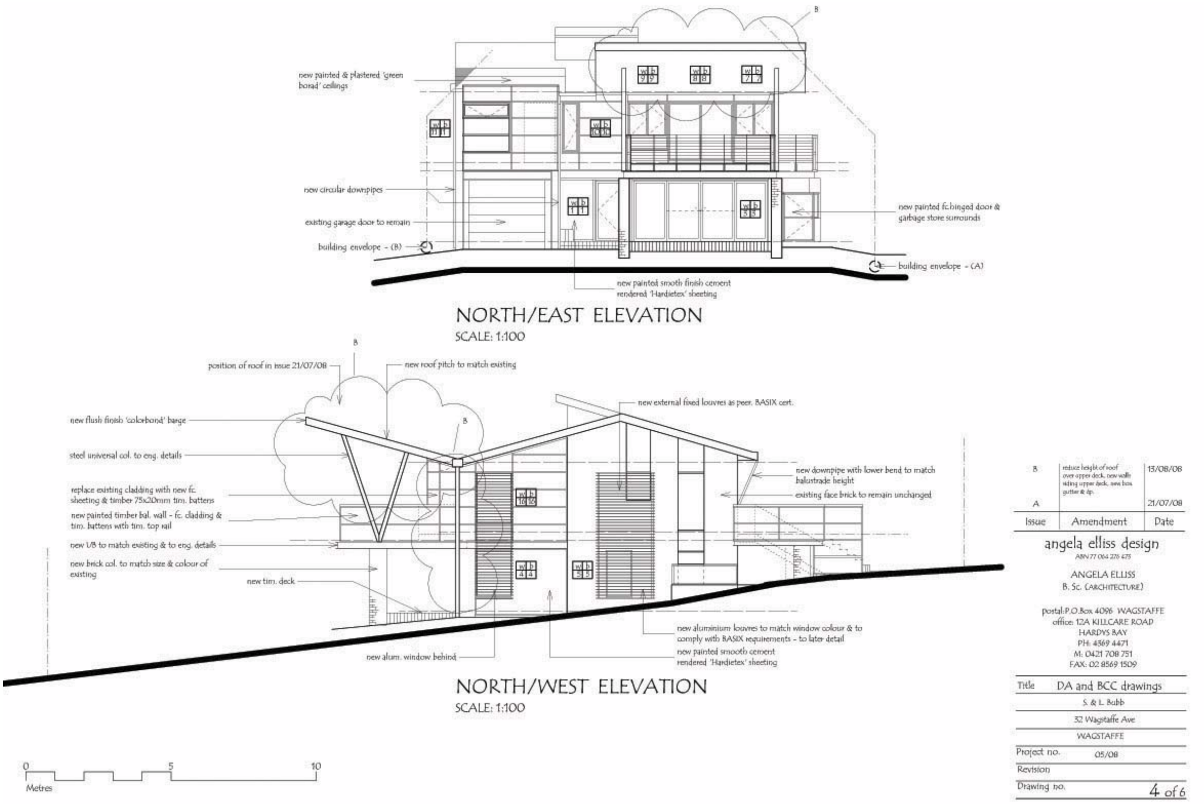
A DA approval is required for a new building and for alterations to an existing building when there is a:

- change in the footprint of the building
- change to the facade ie location of windows and doors and roof line
- structural change ie structural beam added
- alteration to the location of services.

Once the council is satisfied that the development is in accordance with council requirements and that it blends in with the surrounding building, approval is granted and remains valid for 5 years (Oct 2010).

It should be noted that many alterations to buildings are made without DAs. Often the only record of the interior of an existing building is the plumbing diagram, which shows the building footprint and services. It is in fact possible to completely refurbish a house without a DA. Keep in mind that a DA will be required if you are changing the structure or window and door locations on a building.

Currently councils take on average 78 days to assess a new development and 57 days to assess an alternation.



BCC (Building Construction Certificate)

A Building Construction Certificate application is the second part of the council approval process and a Building Construction Certificate will need to be issued by the local council before a development can begin - this includes any clearing that is required before construction. (Councils in other states are likely to have similar approvals.) The building's Design/Construction Drawings and Specification document is submitted to council and reviewed by a Building Surveyor who confirms that all construction types noted on the plans are compliant with building codes and regulations and minimum standards of quality have been adhered to. (See below for more information about these drawings.)

A combined DA and BCC application can be submitted to council, which is cheaper, unless the construction is complicated.

Changes after a BCC has been issued must be approved by council, during construction, may cause non compliance, and require a Section 96 amendment application.

Different documents and drawings may be required at different stages of building.

Site Survey

This is a graphic description of the property and a comprehensive survey usually contains:

- North arrow and scale of drawing
- Location of public thoroughfares
- Site boundary dimensions
- Location of easements
- Location of existing developments and driveways
- Contour lines in AHD levels
- Locations of trees
- Location of fencing and sheds
- Location of watercourses, services, rock outcrops etc

From this a Site Plan and Analysis is created.

This document may include more or less information than the above and is essential in informing councils assessors and neighbours about the proposed development. It is also a valuable document when considering future site improvements. A detailed survey will cost around $1,000.

BASIX Report

BASIX is the acronym for "Building Sustainability Index". Since October 2006 all development applications lodged in NSW for new homes, renovations and additions valued over $100,000 must contain a BASIX certificate. Applications for installing a pool or spa must also include a BASIX certificate. The BASIX certificate pledges the homeowner to water and energy saving commitments that must be verified by an accredited certifier before an Occupation Certificate is issued.

Materials Reuse Statement (sometimes called Waste Management Report)

This is a short 2 page form where the applicant makes a statement to local council how demolished materials will be disposed of, or recycled, and how waste will be managed during construction.

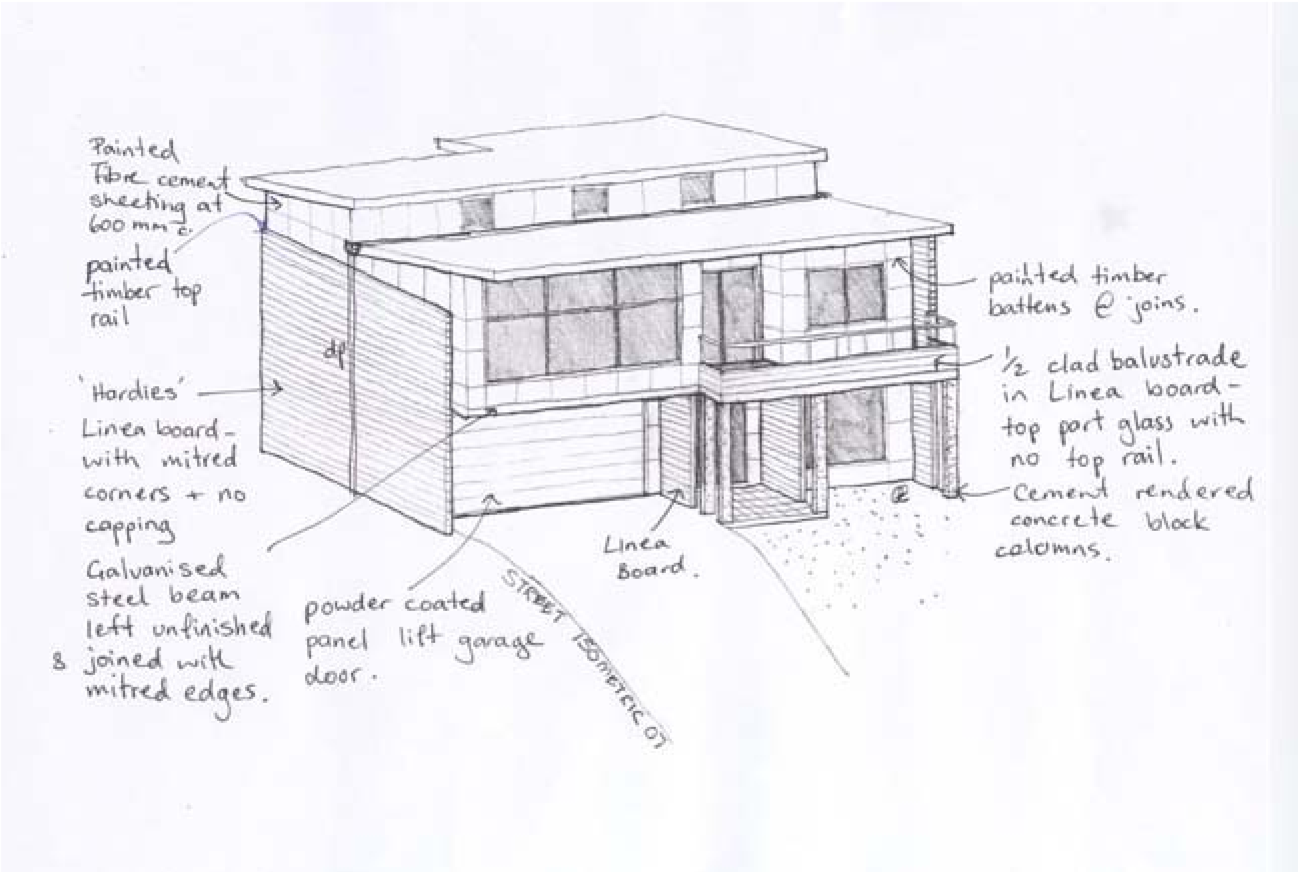
Geotechnical Report

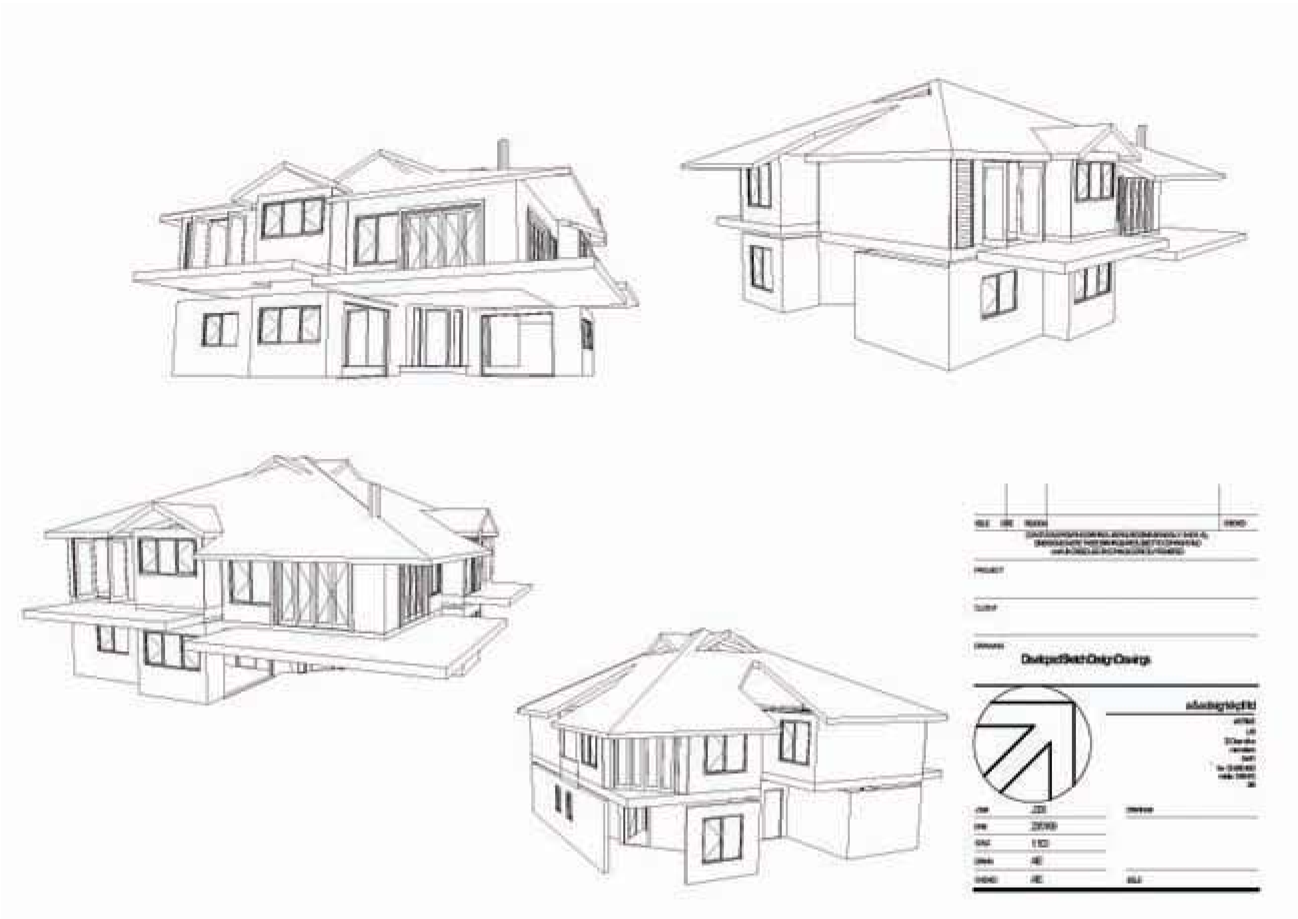
The type of soil determines the bearing capacity (how much weight it can support), and its reactivity (how much the soil moves with different moisture contents).

This report or assessment by a geo-technical engineer is normally requested by the architect or structural engineer. The engineer inspects the site and if necessary, takes soil samples from the site and analyses them in a soil lab. The information in his report allows the engineer to nominate the type of footings required. This assessment will cost around $3,000

Flora and Fauna Assessments

This report is typically required if your site is part of a bushland area. Council will require this report to assess the development and its likely impact on any endangered flora and Fauna. This report may request that no development is to occur in particular areas of the site and will also cost around $3,000

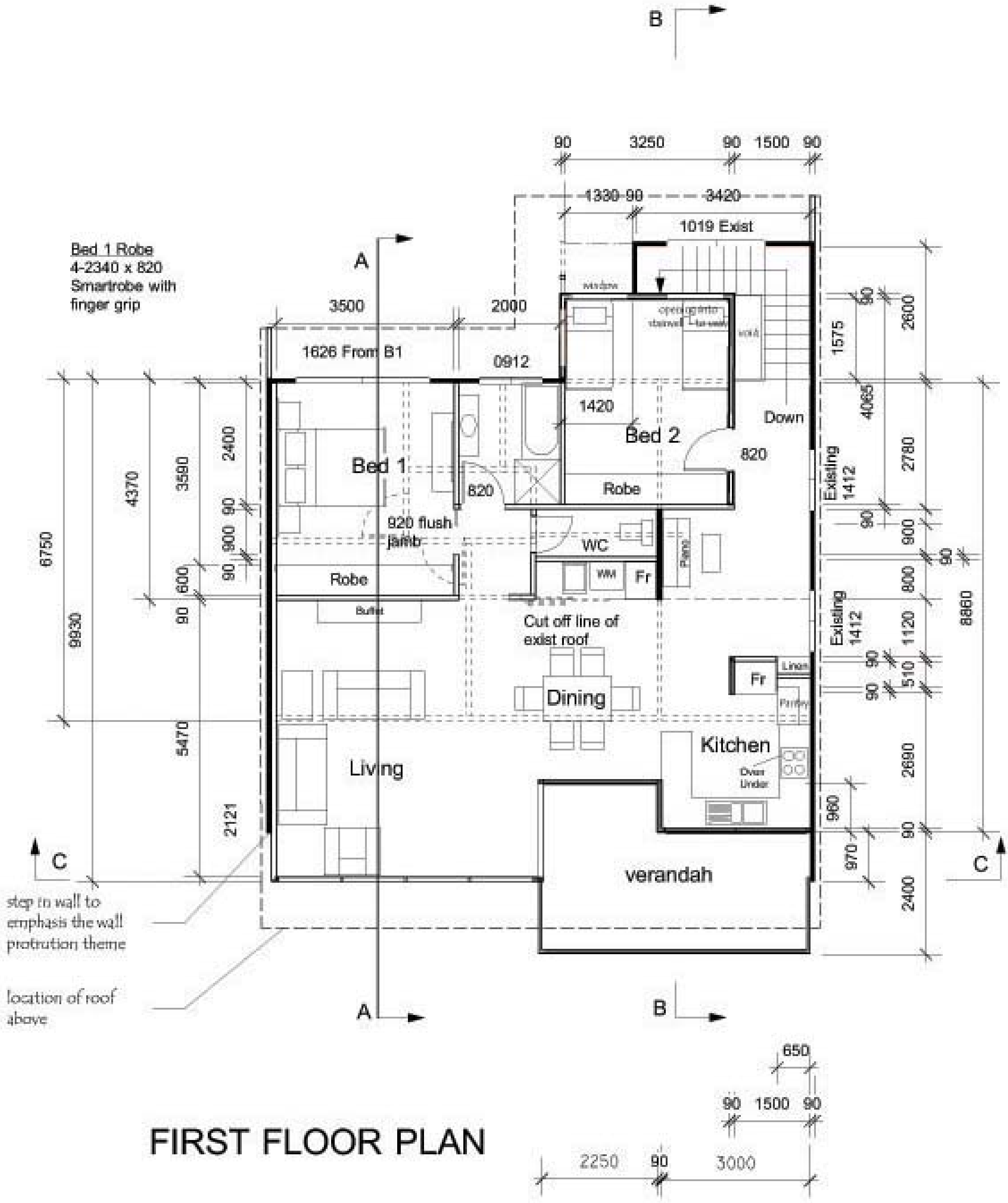

Painted Fibre cement sheeting at 600 mm c.
painted timber top rail
'Hardies' Linea board - with mitred corners + no capping
Galvanised steel beam left unfinished & joined with mitred edges.
powder coated panel lift garage door.
STREET ISOMETRIC 01
Linea Board.
dp
painted timber battens @ joins.
½ clad balustrade in Linea board - top part glass with no top rail.
Cement rendered concrete block columns.



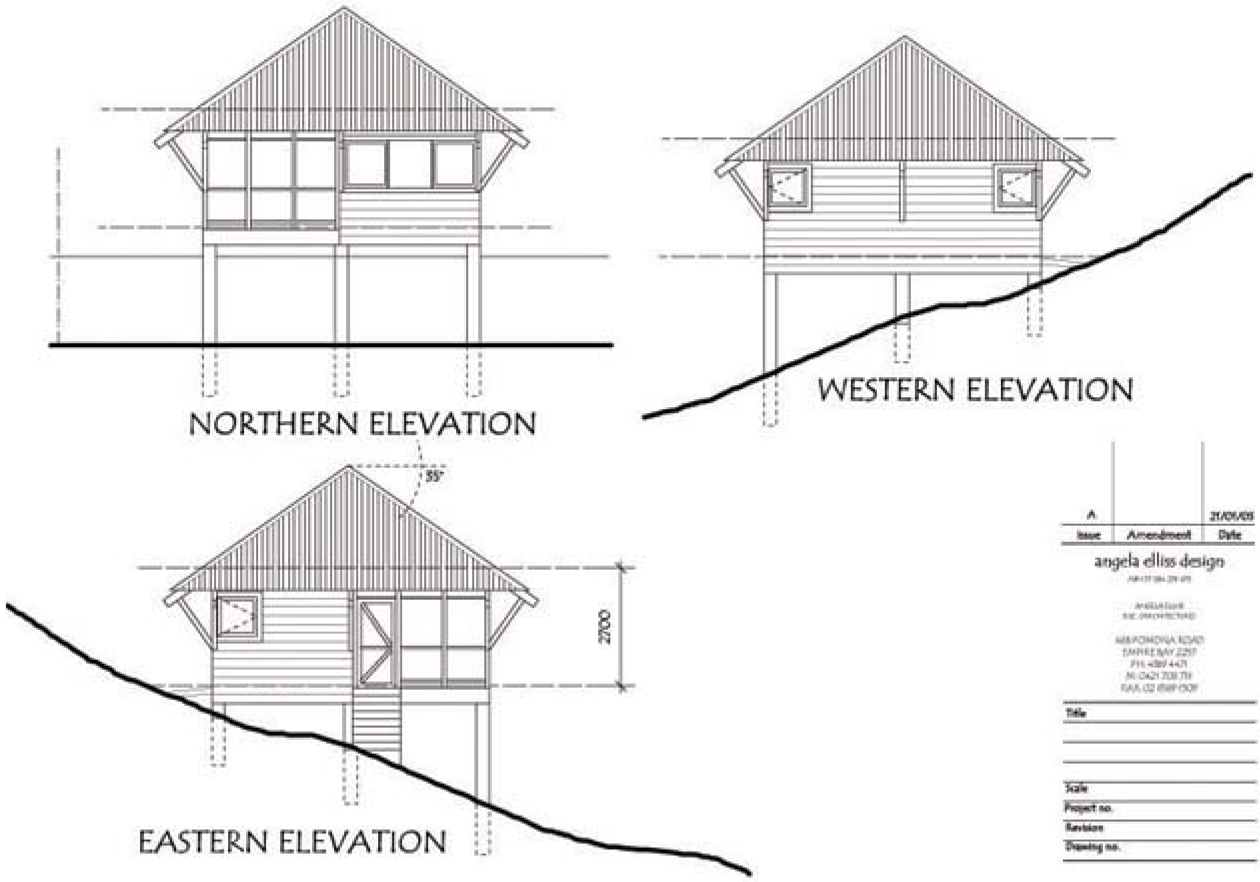
Design Drawings

The architect/building designer or drafts person (designer) starts by drawing some rough sketches which are presented to the client for discussion. Those sketches might be revised a few times until the client is happy. The designer then draws up accurate and complete design drawings for the client and for council approval. They will include plans, elevations and sectional views and may also include a model, three dimensional drawings and detailed drawings. The fees for these drawings will vary greatly depending on the designers qualifications & experience.

Construction (Building) Drawings



FIRST FLOOR PLAN

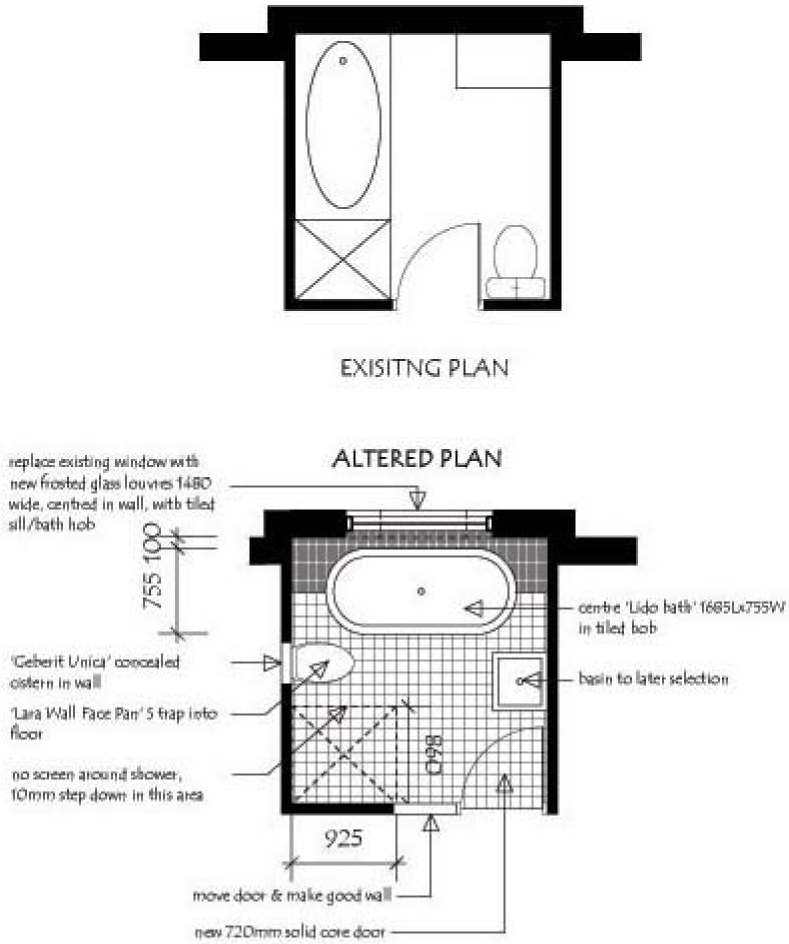


These are filled-out and finalised design drawings of the building that show all sufficient detail to allow the builder or tradesman to construct the building. They will include to scale floor plans that also show front and side elevation, and sections. These drawings will also explain:

- Details of wall dimensions, construction and cladding types
- Heights of balconies and their wall or screen materials
- Roof construction and pitches and cladding details
- Distance of development from site boundaries
- What type of windows and doors are to be used and where they are to be located

Other drawings (will cost extra)

- Service diagrams (electrical and plumbing etc)
- Engineering details for footings and slabs for example
- Wet area details showing bath, toilet and sink locations



Initial design for bathroom

Project Specifications or "Spes"

The "spes" is a working document usually drawn up by the designer - a standard and basic Spes can be purchased from associations such as the RAIA or MBA and can sometimes be purchased at your local council for around $20.

The designers spes is a complete and comprehensive description of various aspects of the building project and includes such things as:

- Site Preparation
- Concrete Construction
- Timber and Steel Construction
- Brick and Block Construction
- Insulation and sarking
- Roofing
- Cladding
- Doors and Window
- Lining
- Trowelled Coatings
- Block and tile Finishes

- Floor Coating and Coverings
- Painting
- Timber Fixtures
- Plumbing and Drainage
- Electrical and Mechanical Installations
- Fences and External walls
- Landscaping
- Pavement and Roads

The Spes is included in the BCC to ensure that the construction and its finishes meet the minimum Australian Standard of quality. This information may also be required by a lending authority.

Detailed specifications also include information about:

- Floor finishes
- Wall finishes
- Size and types of window frames and hardware
- Types of doors and door hardware
- Type of kitchen cabinetry, hardware and white goods
- Type of bathroom cabinetry, shower recesses, baths and hardware
- Style and number of lights

The Specification defines the type of finishes (budget, average or luxury) of the construction. The type of finish can dramatically change building costs, so without this detail it is not possible to cost the finishing of the building. The Spes is also an important guide for tradespeople for it defines the quality and extent of work required and the PC items that need to be acquired by the tradesperson or the owner.

Sample construction specification

Here we have provided a few sample pages from a full construction specification document that building designers and architects produce for clients.

1.1 LICENCE The Contractor and all Sub-contractors are to be licensed as required by law.

1.2 CONDITIONS OF CONTRACT

The Contract is to be carried out in accordance with the standard form of contract agreement General Conditions of Contract (AS2124-1992) issued by the Standards Association of Australia.

1.3 GOODS & SERVICES TAX

All material and labour costs and the Contractor's margin are to include applicable Goods & Services Tax (GST).

1.4 COMPLETION DATE

Tenderers are to advise with their price a period of construction of the new building and this may be taken into account in assessing the most suitable contractor for the work.

1.5 VISIT SITE

The Contractor and all Sub-contractors are to visit the site of the works to acquaint themselves with all conditions relating to their work. No claims arising from neglect of this procedure will be admitted by the Supervisor.

1.6 SITE INSTRUCTIONS

All variations to the Contract will be conveyed to the Contractor by the Supervisor by letter or in site note form. No variations are to proceed without authorisation. The Contractor is to advise any cost increases and extensions of the construction period which may be caused by any variations to the Contract prior to proceeding with variation work.

1.7 MAKE GOOD

The Contractor is to satisfactorily repair any damage to the buildings, existing service lines, or adjoining property incurred by his workmen during progress of the work. It is the Contractor's responsibility to determine the locations of existing underground services and to take adequate steps to avoid damage during the progress of the work.

1.8 SITE FACILITIES

The Contractor is to make temporary arrangements for site water supply, electricity supply and the storage of tools, equipment and materials for the duration of the Works. The Contractor is to provide a temporary toilet and washroom facility located in a suitable position on site and connected to the sewer. (See also Clause 1.29). It is the Contractor's responsibility to keep the washroom facilities in a clean and tidy condition at all times.

1.9 INSURANCES The Contractor is to insure the Works against fire and all other risks for the duration of the Contract Period. The Contractor is to insure in the joint names of himself and the Owner against Public Risk and arrange indemnification in respect of his liability under the Workers Compensation Act of NSW The Contractor is to arrange for Home Owners Warranty insurance in accordance with the requirements of Part 6 of the Home Building Act 1989.

1.10 COVER AND PROTECT

The Contractor is required to cover up and protect the whole of the works from damage caused by weather.

1.11 PROGRESS PAYMENTS

The Contractor shall submit applications for progress payments to the Supervisor at the end of the first four weeks work and thereafter at monthly intervals or as may be otherwise agreed. When requested, applications are to be accompanied by wage sheets, delivery dockets, invoices or other information relevant to the costs of labour and materials claimed. Claims are to include for authorised variations to Contract carried out in the preceding month.

1.12 RETENTION SUM AND MAINTENANCE PERIOD

A sum equal to 5% of each Progress Claim will be retained by the Owner until the Date of Practical Completion, after which date one half of this Retention Sum will be released and the remainder held until expiration of the Defects Liability Period. Alternatively, the Builder may provide security in the form of two Bank Guarantees, each such guarantee being for a sum equal to 2.5% of the Contract Sum.

1.13 P.C. ITEMS

Refer to the Schedules at the back of this Specification and allow in the Tender Price the sums stated opposite the various items for the supply only of these items. The Tender Sum is to include the Contractor's allowance for the complete installation of all P.C. Items where applicable. In the final account, the P.C. Sums listed in the Schedule will be adjusted against the nett costs of the Contractor in the manner set out in the Contract Agreement.

1.14 PROVISIONAL SUMS

Refer to the Schedules and allow in the Tender Price the sums stated opposite the various items of work and materials. In the final account the actual costs of these items to the Contractor will be adjusted against the Provisional Sums allowed in accordance with the Contract Agreement.

8.1 EXTENT OF WORK

Work under this Part comprises the installation complete of all waste and stormwater drainage, sanitary plumbing, hot and cold water service, grey water system and installation of all sanitary fixtures and fitments.

8.2 GENERALLY

Carry out the whole of the soil and waste water drainage in strict accordance with this Specification, the regulations of the relevant Local Government Ordinance(s), Council By-Laws and any specific requirements of the Local Inspector. The whole of the work under this Part is to be carried out by or under direct supervision of a fully licensed Plumber and Drainer. After inspection, testing and approval, cover pipe runs by back-filling with sand to a minimum 75 mm depth above the pipe collars before placing the remaining depth of approved filling material. All existing drainage lines, disturbed, damaged and/or altered during the construction of the new building shall be made good, as required. Drawings showing hydraulic services show the general layout and are diagrammatic only. The Contractor is to prepare detailed layouts of services in conjunction with other trades, and to approval of the Local inspector.

8.3 STORMWATER DRAINAGE

Refer to Engineers Drawings. Surface run-off and where possible sub-surface drainage, is to be collected in a system of charged in-ground PVC pipework and directed to the stormwater silt-trap pit. Drain pit into adjoining Public Reserve water-course with 150 diam PVC pipe and suitable anti-erosion devices as directed on site.

8.4 ROOFWATER DRAINAGE

Roofwater drainage is to firstly be directed into the rainwater tank located under the building. Supply and install a 5,000 litre rainwater storage tank where shown on plan. Refer to Gosford City Council's "Guidelines For The Installation Of Rainwater Tanks" and install the system in full compliance with this document and the requirements of Council's Development Control Plan No. 165 (DCP.165). Tank to be fitted with a first flow diversion device to inlet. Provide overflow pipes connected to inground SW drainage to flow to principal detention tank. Reticulate rainwater to all down-stream garden hosecocks and to lower level toilet cistern. Provide top-up water supply to tank controlled by a float-operated switch.

8.5 STORMWATER PITS

Where shown on the drawings, stormwater pits shall be precast concrete with fitted grated lids equal to C.I. & D. Precast Pty Ltd Model DPM 450 x 450 x 600 deep. Inlets and outlet pipes are to be placed in recessed knock-out sections of pit walls and inverts set min. 75mm above bottom of pit to form silt-trap. Provide removable galvanised steel basket.

8.6 GRATED SW TRENCH

To cross driveway where shown on plan, provide and install a heavy duty grated pre-cast concrete drainage trench equal to C.I. & D. Precast Pty Ltd Model No. TD3, full width and fitted with lengths of 610 x 225 x 20mm cast iron grating. Provide 90mm diam. PVC SW pipe drainage outlet and connect to stormwater system.

8.7 WASTE DRAINAGE SYSTEM

Supply and connect all waste drainage from soil and wastes and fixtures. Provide all necessary pipes, junctions, bends, back vents, gullies etc., and connect to existing sewer main. Allow for all excavation, backfilling, testing and sundry equipment required to complete the installation. Provide and lay runs of PVC drain pipes of required diameters in straight runs, bedded solid on the barrel and with uniform falls. Make all jointing in accordance with current SAA Code. Insert inspection eyes at junctions and in straight runs where directed but not more than 9m intervals. Connect all waste to inground waste-water

collection tank where shown on the drawings. Provide and install a submersible maserating pump and connect 50mm steel rising line to sewer manhole in Macdonald Street.

Electronic specifications can be purchased from such companies as Natspec or Speedspec but cost around $350 per year; they are made for professionals that regularly prepare specifications.

Tendering

If you do not have a builder in mind or if you want to compare prices you can put your job out for tender. This involves getting together all the above mentioned documents as well as the DA conditions and sending them to usually 3 builders. There is a great deal of time and effort that the chosen builders put into tendering so only go through this process if you are serious and ready to build. Set a tender submission date - this reduces the likleyhood of the tender process dragging on for too long.

Building Contracts

There are a few to choose from and they are usually purchased by the builder from such associations as:

- Department of fair trading
- Master Builders Association
- Royal Australian Institute of Architects

There are various types of contracts:

- Small and large residential works - fixed or cost plus (no fixed price)
- Small and large comercial works - fixed or cost plus

The contract is signed by the builder and the client only.

Site Preparation

Site preparation includes: clearing of the site and the preparation of services to the site. Site preparation is generally not a cost that is included in the intial construction cost estimate, because what lies below the surface is often unknown.

Demolition of existing structures

Before demolition can begin:

- All services such as power, water, gas etc need to be disconnected.
- Stormwater and sewer drains will need to be sealed as well.
- Adjoining properties may need to be protected.

- The site must be fenced or suitably barricaded to prevent public access during the demolition process.

New legislation requires that where possible materials from demolition must be retained for reuse, resale or recycling. Recycling commitments will need to be outlined to council in the DA stage.

Where asbestos or materials containing asbestos are involved in the demolition works, compliance with WorkCover or WorkSafe legislation must be maintained at all times.

Establishment of Services

Services are:

- Water
- Electricity
- Stormwater
- Sewerage
- Gas

Council requires that a temporary electrical sub-station and toilet facilities be established on-site before construction commences.

If there are no or insufficient services on site, or they need extending, permission from council and relevant authorities will be required.

Security

A hoarding (site fencing) will also need to be erected and is to remain for the entire construction period.

Sediment control

The builder may have to use a combination of swaling, hay bales and sedimentaion fencing on a sloping block to stop earth falling onto the road or into drains and waterways.

Set out of dwelling

The builder (and quite often the surveyor) pegs out the dwelling footprint from the design drawings. They start at a boundary corner, peg a corner of the building, then lay a string line to describe the perimeter of construction. If the building has walls that step in and out each wall and its change in direction will need to be located on the site - this process usually takes one day.

Setting out, pegging out for a slab on the ground

Setting out is a fairly quick exercise in the scale of things, but obviously it has to be done with great care. A few of the things that I will be mentioning below might sound like I am writing a how to for dummies. Believe me mistakes made in the setting out can come back to haunt you.

I have heard of houses being built on the wrong blocks. I have a friend who when he was planning an extension to his house, found out that his side fence was 1.5M out of position at one corner, in his neighbours favour. The neighbour had a nice brick barbecue built partly on the wrong block land. the neighbour was understandably peeved when he was asked to remove it. (Plus the expense of new fence etc.).

Setting out - A concrete footing with a profile in the foreground. In this case it uses star pickets for the pegs and the timber is fixed with tek screws through the holes in the picket. Quick, solid, easy and reusable.

First checks, before you start.

- I am assuming that the relevant permits to build have been obtained.
- You should have an accurate block plan, with the lengths and angles of all the boundaries marked on it.
- Use it to check **every** fence line. You may have to buy or hire a long tape measure for this. I have used steel ones in the past, but they are expensive and prone to

damage. I have had a 50M fibreglass one for years. It is not as accurate as a steel one (they stretch a touch) but it is indestructible.
- Every time that I have built on a boundary line (not a fence, but a proper building) I have had a certified surveyor to do a check. I just don't trust the existing fences. The very last job that I did, our surveyor pitched up an 85 to 50 discrepancy in one of the boundary walls. (The builder who put it in was a bit like me, and on the cautious side, he gave us the odd 50mm just to make sure). I could quite easily have assumed that the wall was OK and built partly on his block.

Preliminary site works.

First off tidy up the site, remove all trees that are in the way. We all love trees on our blocks, but don't try to save ones that are just too close to the new building. They are an absolute pain to work around with scaffold etc. and they usually have to go in the end anyway.

- On the drawing there is always one point and one line, or two reference lines that cross one another, given to start the set out.
- Usually they are referenced to a couple of boundary lines, or an existing building.
- Go around with a few steel pegs and bang them in near enough at the corners of the proposed slab.
- From them mark out roughly the area of the job.

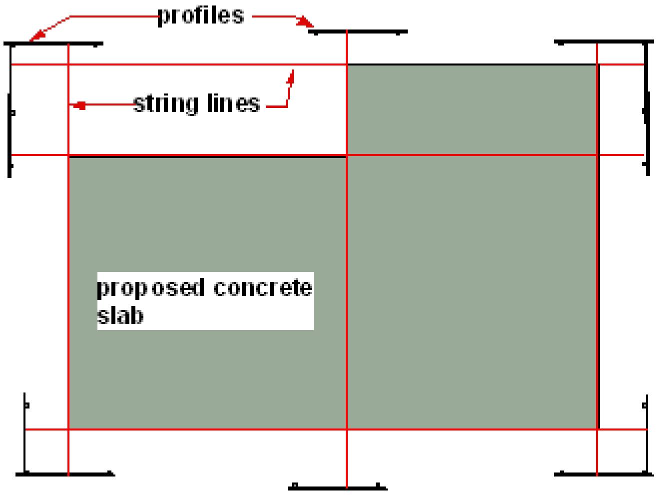
Somewhere on your drawings or in the building specifications there will be a clause that says something to the effect that you should strip the area of the work plus an extra 1m all around, of all topsoil and deleterious materials to a min. depth of 150. before starting to place the compacted approved fill. This means get rid of all vegetable matter, grass tree roots etc.

Get a machine in to clean up and remove top soil.

First layout

1. Go around again and put in pegs for the corners more accurately this time.
2. At this stage your pegs can be short wooden things that you can tap a nail in, steel rods, even screwdrivers or just besser blocks placed on the ground.
3. Anything that will give you the positions of the corners.
4. As you do this do checks for square. (See section on squaring below).
5. At this stage, if the job is small and you getting machinery in for excavation work, you may put string lines between the pegs, and mark out the lines of trenches, or pier holes with lime.
6. You could then get the excavation work done first, before going on to the next stage.

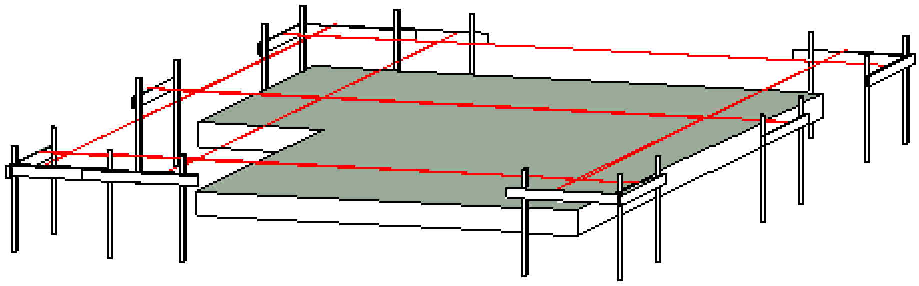
Profiles, batter boards or hurdles.



Setting out - A plan of a concrete slab showing the profile positions.

Profiles consist of pegs, stakes or pickets, driven into the ground, with cross piece of timber attached to them.

Like formwork they are only temporary and as such they don't always look too neat, made up of all sorts of odds and ends and yet they have to contain quite a lot of information, even on a simple house extension.



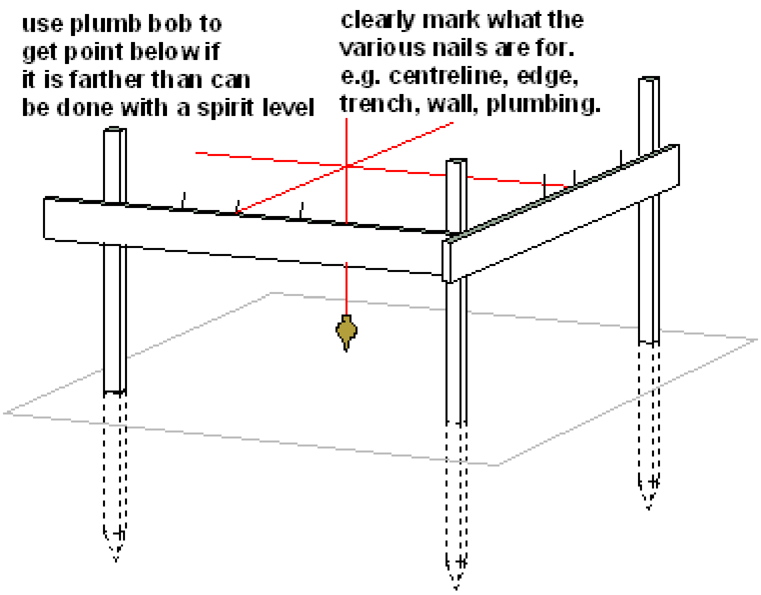
Setting out - A 3D view showing the use of profiles on the above slab.

They are used to transform the original pegs in the ground to something that is a semi permanent but accurate reference of the important sizes, measurements and offsets etc for a particular stage of a job. In the case above, when the concrete slab is poured the profiles can then be removed, because further measurements can be made from the actual concrete.

For the slab drawn, you may have marked on the profiles, before the excavator starts work:-

1. The position of all the foundations, for external and internal walls.
2. The wall positions to let the plumber accurately to position his sewerage pipes and floor wastes. To let the concretor place wall starter bars in the slab or column HD bolts.
3. Possibly underground power supply and entry point.

- The first trade to use the profiles will be the excavator, so a reasonable clearance between the work and the profile itself is needed, to allow the machine to do it's job without squashing a hurdle out of there.
- In the sketches shown here I have shown them marked out with the overall sizes of a concrete slab.
- They could just as easily have a set out for the width of excavation trenches etc.
- Quite often a profile may consist of a board nailed to an existing boundary fence. There is no absolute rule, just something that can be marked out, take a nail or a screw and is fairly robust so it can't get moved out of position easily.



Setting out - A hurdle or profile used for setting out.

In most cases the guy on the job, say the plumber setting a floor waste or the carpenter fixing the perimeter formwork, will use a spirit level to plumb down from the string line to his job.

Many times, in sloping ground or when working in an excavation where it is hard to use a level, then the plumb bob can be very effective. I have used it in basement type situations where I simply hang the plumb line off the profile lines. I use a tie wire hook through a slip knotted loop to adjust the length of the plumb line.

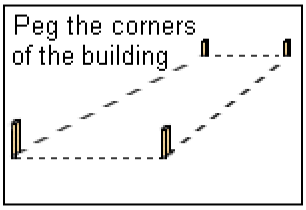
A lot more convenient than straight edges and spirit levels.

Building Profiles

How to establish the building line (profile, perimeter of a building) and ensure it is square and level. Suitable for square or rectangular buildings.

1. Peg the four outside corners:

Determine the location of the building in relation to other buildings and boundaries (as usually shown on the site-plan or other relevant plan), and place pegs in the ground marking the four corners of the building.



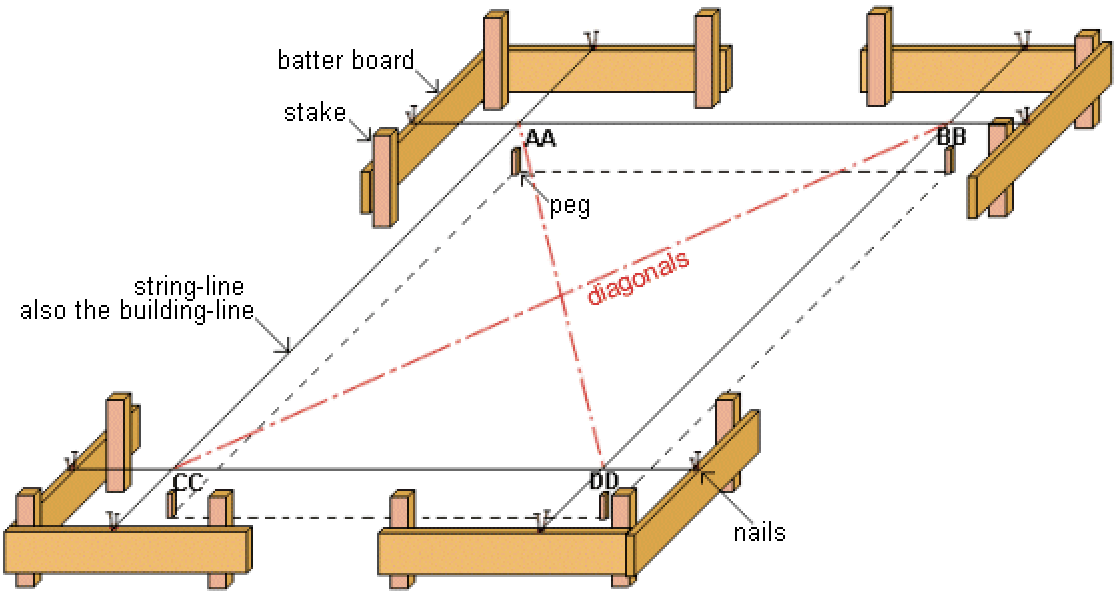
Check to see if the pegs are square and form an exact rectangle. This can be done by making sure that:

 1). Line **AA-CC** and line **BB-DD** are parallel. Line **AA-BB** and line **CC-DD** are parallel.(as shown in the drawing below)

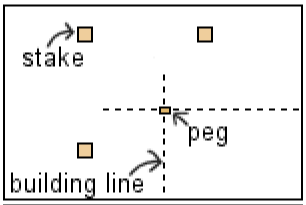
 2). The distance between peg **AA** and peg **BB** is the same as the distance between peg **CC** and peg **DD**.

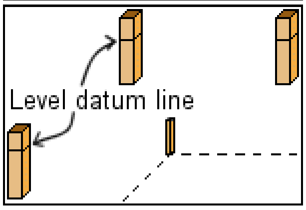
 3). The distance between peg **AA** and peg **CC** is the same as the distance between peg **BB** and peg **DD**.

 4). The distance between peg **AA** and peg **DD** (the diagonals) is the same as the distance between peg **BB** and peg **CC**.



2. **Hammer in the stakes and mark the height:**





Cut 12 stakes 600 (2ft) long, out of 50x50 (2x2) stock (or similar). Cut a point at one end of each stake so they can be easily hammered into the ground.

Position the twelve stakes as shown in the diagram (3 at each corner) and hammer them firmly into the ground.

Note: If the ground is sloping, then the stakes will need to be longer at the lower corners to compensate.

The stakes should be at least 600 (2ft) out from the building line to allow room to dig the corner footing holes. If a machine is required to dig the footings, then the stakes will need to be further out from the building line.

Make a level mark on all twelve stakes beginning approx 150 (6") above ground level, at the corner where the ground is the highest (if the ground is sloping). Keeping the batter boards close to the ground saves the need for bracing. The height is only a reference height, so it does not really matter if the marks are slightly higher or lower, as long as they are all level. The water level method is one way of finding accurate levels.

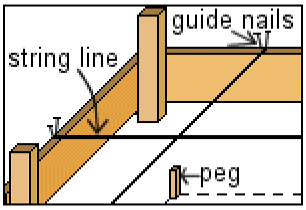
3. **Fixing the batter boards to the stakes:**
Once a level line has been established and marked on all twelve stakes, proceed nailing batter boards to the stakes, so that the top of the batter

board is flush with the level line marked on the stakes.

The batter boards (8 in all) can be 100x25 (1x4) or 150x25 (1x6), and of boxing grade or low grade stock. Depending upon how far the profiles are set back from the building line, each can be about 1500 (5ft) long.

4. Put up the string line:

Run a taut string line from batter board to batter board, passing directly over the pegs. Fix to each batter board between 2 nails, which will act as guide nails.



This will now show the approximate building line and perimeter of your project, but more exact measurements are needed.

5. Parallels and Diagonals:

The following exercise is the same as in STEP 1. where the pegs on the ground were checked to ensure they were parallel and square. This time, the string line directly above the pegs needs to be checked so that it is also parallel and square.

Check that the distance between the string line at point **AA** and **BB** and the distance between **DD** and **CC** are equal. If not, make any necessary adjustments by moving the string line in or out along the batter board and adjust the guide nails accordingly. The distance between **AA** and **CC** and the distance between **BB** and **DD**, also need to be equal. Make any necessary adjustments

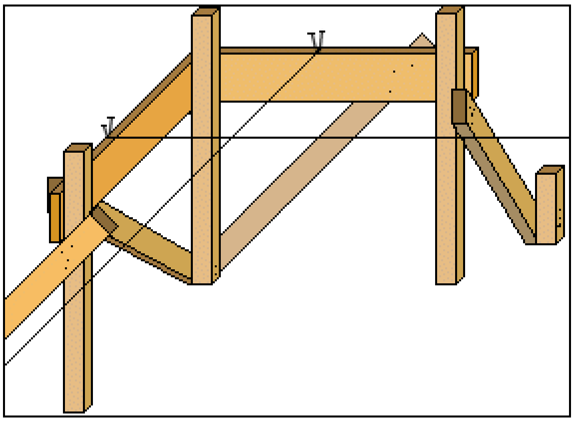
Once the perimeters are parallel, the diagonals need to be measured to ensure that the building line is square.

Do this by measuring the distance between **AA** and **DD** and the distance between **BB** and **CC** (the diagonals). Make any necessary adjustments to ensure the diagonals are equal and if adjustments are required, re-check the parallels again, since altering the diagonals will also change the parallels.

When the building lines are parallel and the diagonals are equal, the building line is then square. You now have a level, square building line to work from.

NOTE 1. In this example, the height of the string line, which borders the perimeter of the building, is a "datum" or reference height. This means it is not a specific height for anything particular, therefore any specific building height can be measured down from, or up from the string line. For example: if the string line is 200 (8") above ground level where the ground is at its highest point, and the foundations are to be 150 (6") above ground, then the foundations will be 50 (2") below the string line all the way around.

NOTE 2. If the profiles are high enough off the ground to allow sway movement, then the profiles will need to be braced. See below.



Getting it square.

In my opening paragraph I mentioned that mistakes in setting out can come back to haunt you. One of the classic mistakes is getting the floor plan out of square. It has repercussions for the roofer, but worse still is when you have the floor tiler in towards the end of the job and you can't escape the fact that the width of the tiles varies from one end of a wall to the other. Far easier to get it **right in the setting out**, **right in the concrete** (check the formwork before the pour) and right when laying out the **internal walls**.

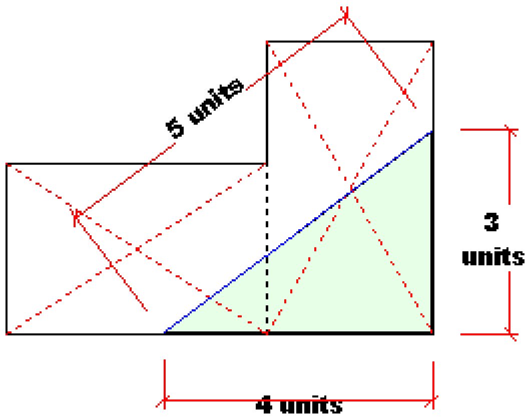
We mainly work with rectangles in building work. A rectangle has the following attributes which help us in setting out building work.

1. **Each of the four angles is 90 degrees**, or square as we call it.
   Great, this means that if we have a base line side set up, and then get a second line set up off it at the right spot, at 90 degrees to the first we have two of our side done.
2. **The opposite sides are parallel**, that is, they are the same distance apart.
   That is it! Measure the correct length from one end of the first side and the **same**

length from the other end and we have our third side fixed. Do the same again and we have our fourth side. That could be it - finished.

3. **The diagonals are equal lengths.** That is the length from one set of opposite corners is the same or equal to the length from the other set. This means that if we have got a touch out with either of the first two steps (as you do:-), we have an excellent way of checking our set out

Diagonal measures work well when they are at a reasonable angle. When the rectangle is long and narrow then the angle is flatter this way is a less reliable way of checking.



Setting out - Using a 3,4,5 triangle

Look at the sketch here. Let's say it is a plan of a house slab that you have to form up.

- You should first have an idea of which will be the most important side, that the rest are made square and parallel to it.
- Split it into rectangles and check the diagonals for equal. The dotted red lines.

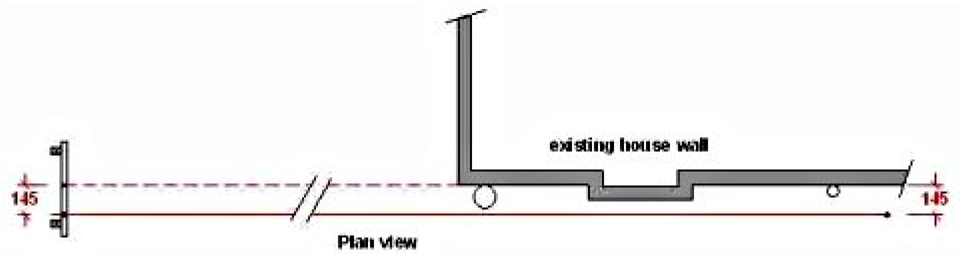
Also on this plan I have incorporated a right angle triangle known to builder's the world over as a three four five triangle.

In our setting out of the rectangles in the sketch you can clearly see that each rectangle could be also seen as two triangles.

- Two thousand five hundred years ago the ancient Greek philosopher and mathematician Pythagoras discovered his truths about right angle triangles.
- Anyone with a cheap student's calculator can use Pythagoras' theorem to get the length of the diagonal side if you know the lengths of the other two sides. (The sum of the squares of the two shorter sides is equal to the square of the other).
- There is a unique triangle that is often used to demonstrate this principle, 3,4,5. ((3x3=9)+(4x4=16) 9+15=25, so does 5x5=25)
- So any triangle in this ratio, will have a 90 degree corner opposite the long side.
- Ratio is the key word.

- The units don't matter as long as the ratio is the same.
- 3,4,5 miles, or 3,4,5 centimeters, the right angle is still there.
- So If we are looking at a house plan in the sketch above, I could use say 2M as my unit.
- I would bang a nail in the formwork 8M (that is 4units of 2M each) from the bottom right hand corner.
- Another one would go in at 6M (3units of 2M) along the other edge.
- I would check the distance with my long tape between the two nails and if it was within 5mm of the 10M (5units at 2m) that I was expecting, I would modestly say to my offsider, "crikey we were lucky there mate".
- If it was a bit more out like 40mm or so then I would move the nail holding my string line on the profile to correct the error, and then work from the altered line, thinking myself lucky that I had checked the set out before we had done a lot more work.

Offsets



Setting out - Offset line around obstacles.

It is not good practice to use only a short section of an existing wall to get a line that is a continuation of it. Far better to try to use as much of the existing wall as possible, even if the wall has obstruction in the way. The way to do it is simple, offset the line around the obstacles.
Even if the wall is clear, using an offset is the more accurate way, because there could be local bumps in the wall that could throw your line off.

- In the sketch above I show a method of using the profile to offset the line to miss obstacles and then reset to get the point that is a true extension of the main building line.
- I want to mark out, on my profile (to the left), a building line for a new extension, that is exactly a straight continuation of the main house wall.
- I just pick a distance from the house that gets me clear of the various obstructions. In this case it is 145mm.
- I make sure the string line is offset the same distance from the house,and then I put a nail or a screw into my profile at the continuation of that line. That is I place a line parallel to the wall 145 off it.
- I then measure back the offset distance to get a point exactly in line with the wall.

- I bang a nail into a brick joint or a peg touching the wall, and string a line, shown dashed, to fix the true building line.

One a similar vein, sometimes when you have to get machinery into a job, rather than just pull out the profiles that are in his way, first set up some offset or recovery profiles. Say you set the recovery profile 6M away from the real one, then it is a case of a simple 6M measurement offset to get back to the original set out, and reinstate the original profiles, rather than starting from scratch again, squaring etc.

Setting out on-site

1. First step is to set up a reference stringline. I found the best way was to establish the string line for the front of the house, as I had already marked where that would be.
2. Next, measure forward of that line 2m and knock in pegs for another line that will be first side of your "envelope". So now you have your first two horizontal lines. Note that they are longer than the envelope at this stage.
3. Now we will create the first vertical line. Lets do the left-most edge of the house (as viewed on the plan). Knock in a peg at the top envelope line where the left edge of the house will be. Attach a string and walk it out the distance you know it should be to the opposite side of the envelope (vertically), then a bit more. You will now use the 3,4,5 rule. That is, you can check the square of something by measuring 3 metres along one stringline, 4 metres along the other and when the distance between the two marks is 5 metres, you have an exact square. Put a mark along the top line from the peg you just put in at 3m (texta works well). Next measure down the vertical line from the peg 4m. Move the vertical string sideways until the measurement between those two points is 5m. You can then knock in the bottom peg of your vertical line.
4. Next you can measure out your two metres to get the left side of the envelope and mark out as shown below. You now have two sides of the house and two sides of your envelope.
5. Use your 3, 4, 5 trick again to set out your next outside line as below, then set the next horizontal house line as well.
6. Keep working around each side until your stringlines look like the diagram below.
7. Your site won't be flat even if your excavator guy says it is! I had access to a laser level; hire one because it's worth it. You could also use a dumpy level or a water level (although that could be tricky because in most cases you will be close to the ground, easier with stumps). Take a height measurement at each corner of your envelope. We need to set the hurdles high enough so that the stingline is 150mm above the height of the finished slab. This should be detailed in your engineering details - ours was 150mm above ground, so I set my stringline at 150mm above that, to give a finished height of 300mm (close enough to be able to transfer measurements, high enough that they are out of the way). So, find the lowest point and the highest point.
8. Using the highest point, knock in a peg to the desired stringline height. This will now be a reference for the other corners of the envelope. Put the laser level measuring pole on top of that peg and adjust the height to zero. Now go to the other corners

and knock in pegs until the top of each is equal to the same height i.e. the measuring stick indicates the height is level with the reference peg. You can now put nails in the top of each peg and run a stringline all the way around; you will have a level and square perimeter around which to put in your hurdles and the stringlines will tell you how far to knock in your hurdles so they are at the desired minimum height.

9. Next, replace the peg marking the left-most vertical line (the house, not the envelope), with a hurdle. I used jarrah garden pegs (buy packs from hardware stores) and non-structural pine for the top (very cheap). Go back to your plan and look at how many string lines meet this hurdle and knock in sufficient pegs along the envelope line down to the stringline. Now cut a piece for the top that is long enough to receive the planned stringlines and screw it to the pegs. I made up all my hurdles ahead of time, which was a mistake; the force of driving in the pegs broke some of the tops and I had to repair/remake.
10. Put a nail in where the stringline marking the edge of the house should go. Now go to the other end and repeat the process.
11. Do this for each of the hurdles marking the outer edge of the house until you have all of those stringlines set up on hurdles i.e. no longer on pegs.
12. The next step is critical; it is highly unlikely that that rectangle will be perfectly square as things will have moved and all the steps above are really a "rough-in". Now we need to check EXACT square.
13. First, double-check that the top line marking the house is the correct overall distance to the bottom line by measuring at each end. Check the other two parallel sides. Now we need to check the diagonals. With your assistant, have them hold one end of the tape measure and walk out to where the opposite corner is, where the stringiness intersect. It should be exactly equal to the value you calculated above. If not, check the other diagonal; one should be over and the other under. Adjust the nail positions ONLY on one side (so you know the overall width won't change) e.g. if you are doing the vertical lines marking left and right, leave the nails at the top in and adjust the bottom ones. You may need to adjust things a few times. I was told that if I got it within 5mm that would be very good, and in the end I think Brett & I got it within 2mm.
14. Now all there is to do is to run along each side and putting in hurdles/nails based on your plan. As you go use a texta to write the stringline number next to the nail.
15. Finished, nice square house and a happy concreter/builder! Oh, double and even triple check all your measurements….it's important.

Floor Construction

Note: Before selecting any structural components for your dwelling it is advised that you consult with a Structural Engineer and a builder. In addition you can read the Australian Standards available for all areas of construction.

Footings

Steel pole house with exposed structure

Trenches with reinforcement for strip footing

The type of footings used for a new home will be suggested by the home designer with possible consultation with a geo-tech consultant. The factors that influence the type of footings are:

- Weight of building
- Wall construction type and height
- Soil type
- Slope of the block
- Budget
- Drainage requirements on the block

There are five main types of footings:

Strip Footings

A Strip Footing is a relatively small strip of concrete placed into a trench and reinforced with steel. The footing supports the load of the exterior walls and any interior wall that is load bearing or supports a slab such as for a bathroom. Strip footings can be used for both traditional timber and concrete floors. They are one of the most common footing used in Australia.

Concrete pad footings.

A concrete pad footing is the simplest and cost effective footing used for the vertical support and the transfer of building loads to the ground. These footings are "isolated" ie there is no connection between them. They are also reinforced.

Holes are dug (say 400mm wide x 400mm deep) into the ground and fitted with a reinforcement cage then filed in with a concrete mix to ground level.

Concrete pad footings are used to support light weight timber-framed houses.

Pole Construction (Post and Concrete)

For this type of footing a hole is dug into the ground about 800mm wide x 1600mm deep. A pole is then placed into the hole and ready mixed concrete is back filled around the pole. Pole construction footings do not require steel reinforcement (or an engineer) and are therefore also one of the least expensive footings types.

Concrete strip footings
with reinforcement

Pole Construction is the most economical way of constructing a pier/footing on sloping land but engineer's details will be required for the builder and certifying authorities. A few essential considerations are:

1. How long the poles will need to be and the spacing?
2. What will be the correct height of all poles?
3. How far down will the pole will need to penetrate?
4. How will the concrete around the pole need to be finished to reduce wood rot?
5. What will the diameter of the poles need to be?
6. What are the poles are made of (steel or timber)?

Grout Injected Piles

Where it is impossible for a footing to be constructed, a pile which is both pier and footing is used.

This method is only used in unstable or potentially unstable soils such as mud flat estuary areas and beach front etc. Grout injected piles are "isolated" footings and/or piers, which are cement grouted (not concrete) and steel reinforced, with an overall diameter of around 600mm.

The piers are installed by inserting a cork like screw (Metal Auger) attached to a Backhoe in to the ground. The Auger screws all the dirt out of the pier hole that will be around 6 meters in depth. Once all the dirt is removed the grout is injected through the end of the rotating Auger into the hole. As the hole fills with grout the rotating Auger is slowly removed ensuring no dirt collapses back into the hole. The Auger machine drills out the pier holes with minimal disturbance to adjoining soil and structures. Mini piles use the same process and materials as grout injected piles but are around 200mm in diameter

Timber Piles

Timbers piles are a more cost affective method of constructing structural piles. Timber piles are long timber poles around 6000mm in length and 400mm in diameter that are hammered deep into the ground by a pile driving rig (big hammer). The piles are driven into the ground their full length or until the pile hits bedrock. If the pile hits a floating bolder it will skew in the ground but the pile will be amply stable to support a floor structure. Pile driving vibration can disturb adjacent buildings, resulting in cracking, failure and even collapse.

Floor structures

Pier and Beam construction

Piers are the most common and cost effective type of floor support system used in NSW, and to a lesser extent, other states. The piers sit directly onto the concrete pad footings and can be:

- brick piers
- timber stumps on galvanised "shoes"
- steel posts that are bolted in each corner onto the pad footing with a "Dynabolt"
- precast reinforced concrete
- core filled concrete block work

Bearers and joists

The bearers rest on top on the piers and usually run the direction of the longest wall. Joists are then laid in the opposite direction and are often clad in chipboard before the final floor is installed at the end of the construction process. Do not forget at this time to allow access for bathroom and kitchen piping.

Physical termite barriers like "Termimesh" (stainless steel mesh) or "Graniteguard" (a fine dry granular product that when compacted stops termite entry) will be located between all connections to timber flooring members. These connections materials include concrete, steel and brick.

Concrete Slabs

There are two main types of ground slabs:

Raft or Ground Slab

The steel reinforced raft slab is the simplest and most common slab construction available. In each case:

- Trenches about 450mm wide x 450mm deep are dug around the perimeter of external walls and under load bearing walls
- Reinforcement cages are laid in the trenches and reinforcement bars are also laid at this time, and turned up to pass above the top of the strip footing to accommodate later slab structure
- Ready mixed concrete is poured into the trench to ground level with vertical reinforcement bars protruding up to be formed with the floor slab.
- Moisture protection, termite protection, electrical conduit, drainage and sewerage pipes for bathrooms and kitchens are positioned.
- Form work for the slab is then erected along the outer edges of the building footprint and on top of the cured concrete footings.
- Steel reinforcement is laid for the slab
- Concrete is poured in one operation creating a slab that covers the entire floor area.

Waffle Slab

Waffle slab example

A waffle slab is like an egg box arrangement i.e. it is not a solid slab.

Trenches are dug perpendicular to the perimeter of the building's footprint. Steel reinforcement is laid in the trenches to give it a rigid structure. Large polystyrene squares are laid between beams (instead of aggregate and sand). Concrete is poured in one process (rather than the separate pours in for a Raft Slab)

Waffle slabs use less concrete, however if well engineered, they can be stronger than a solid slab .

Suspended slab

Suspended slab example

A suspended slab is raised off the ground and has an accessible sub-floor area. In a residential situation the slab is around 200mm thick and is supported by external sub-floor walls of brick or concrete block etc. The slab is also supported by free standing brick or concrete piers.

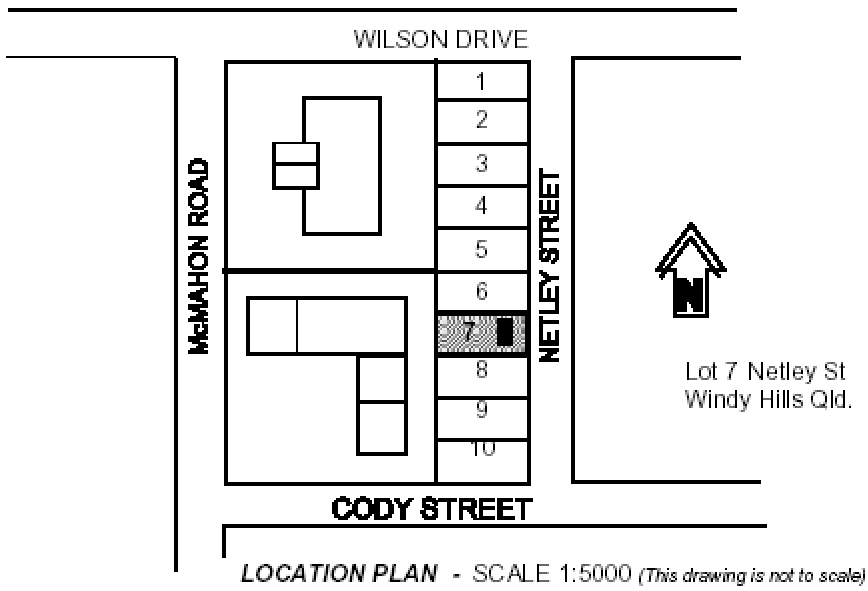
To reduce the concrete slab thickness a sheet metal product such as 'Bondek' can be laid as not only the form work but also a structural component. This steel sheet product is designed to take the pouring and curing loads of concrete and is very strong. 'Bondek' can reduce slab thickness hence reducing concrete costs. This sheeting is not removed and remains in the structure for the life of the building.

How to read house construction plans

Location Plan

A location plan may be required if it is a big development so that the relative location of the site in a particular street is clear. It will show lot numbers, deposit plan numbers and a north point, using various scales but usually 1:5,000.

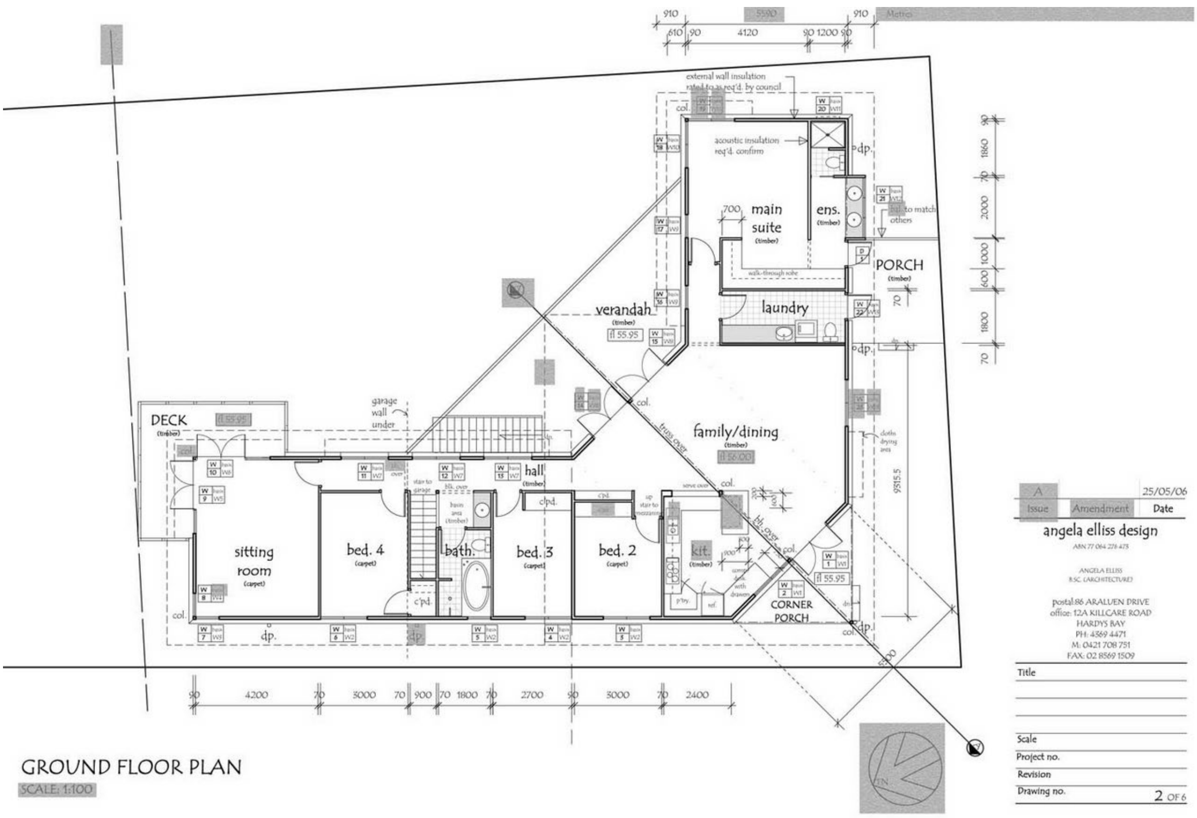
Location Plan



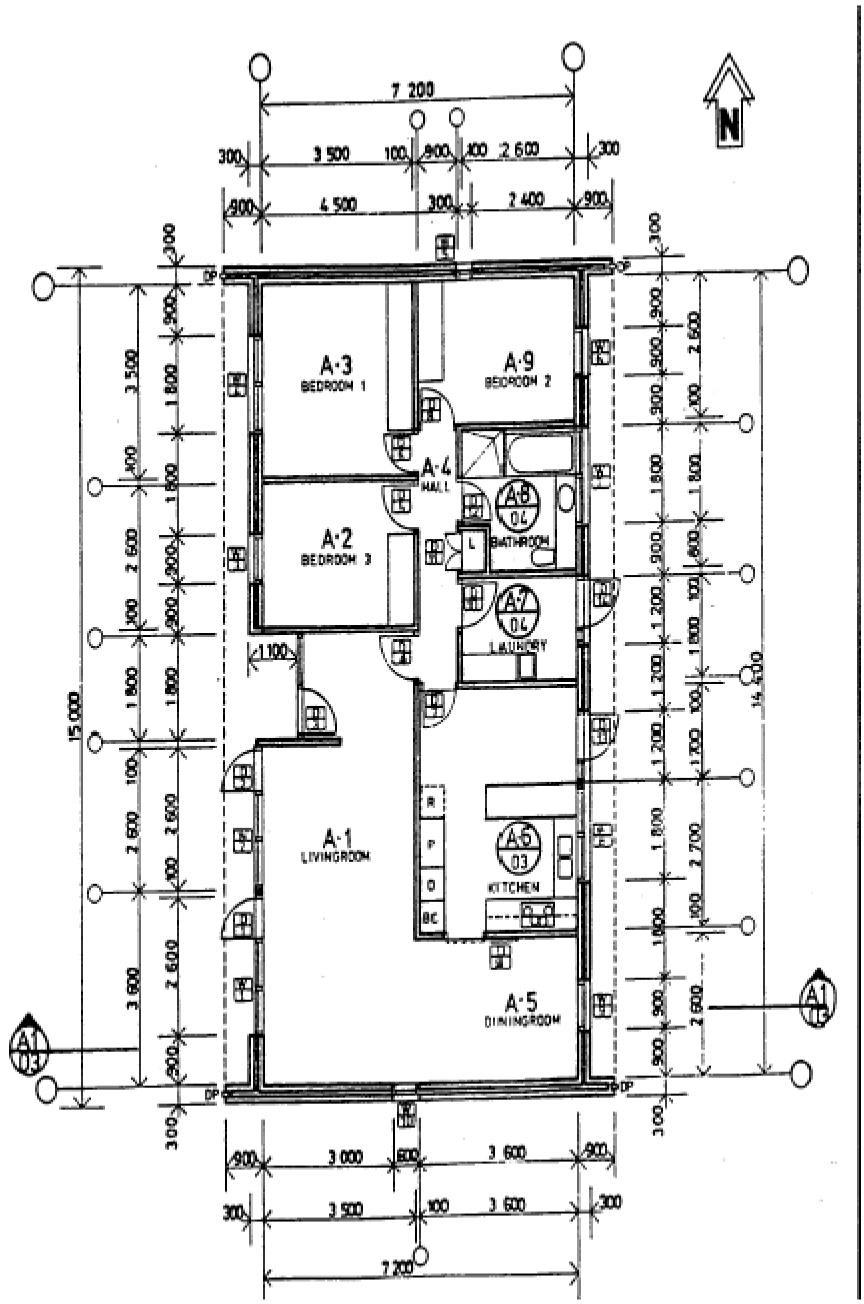
Explained below are 5 types of construction plans: floor plans, site plans, sub-floor plans, elevations and sections.

Plan 1: Floor plan

A floor plan is an overhead view of the completed house (with the roof removed). You'll see parallel lines that scale at whatever width the walls are required to be. Dimensions are usually drawn between the walls to specify room sizes and wall lengths. Floor plans will also include details of fixtures like sinks, water heaters, furnaces, etc. Floor plans will include notes to specify finishes, construction, methods or symbols for electrical items.


GROUND FLOOR PLAN
SCALE: 1:100
main suite
ens.
PORCH
laundry
verandah
family/dining
DECK
sitting room
bed. 4
bath.
hall
bed. 3
bed. 2
kit.
CORNER PORCH
angela elliss design
postal:86 ARALUEN DRIVE
office: 12A KILLCARE ROAD
HARDYS BAY
Title
Scale
Project no.
Revision
Drawing no.
2 OF 6

AN EXAMPLE OF A FLOOR PLAN - SCALE 1:100



- These are horizontal sections through the building viewed from above. They can be drawn at various scales, but usually 1:100.

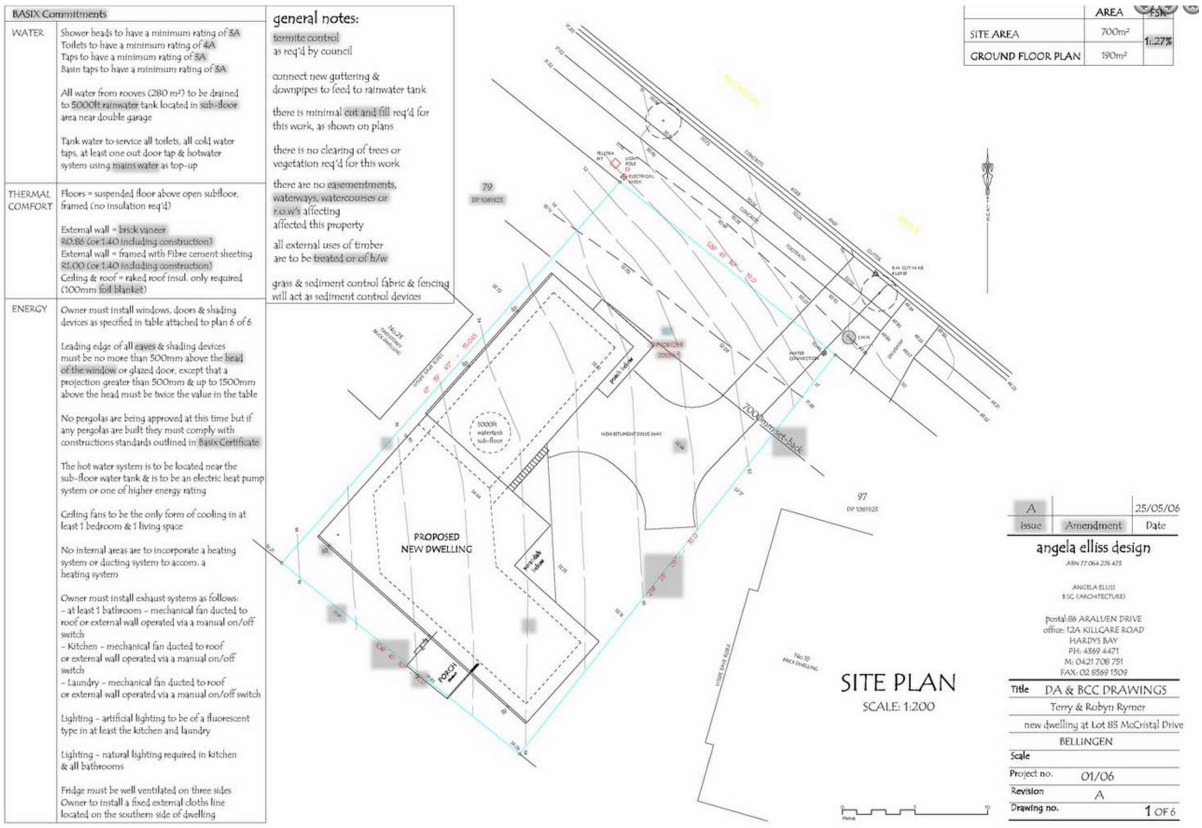
What do floor plans identify?

- Floor level - e.g. ground, garage, first floor etc.
- Room names and their internal sizes.
- Width of openings and thickness/type of walls, - e.g. brick, timber.
- Overall dimensions of the building, cupboards, halls and spaces.
- Position of fixtures - e.g. for wet areas such as bathrooms, kitchen and laundries, the position the bath, shower, toilet, cupboards, basins should be indicated.

- Type of floor covering may also be shown.

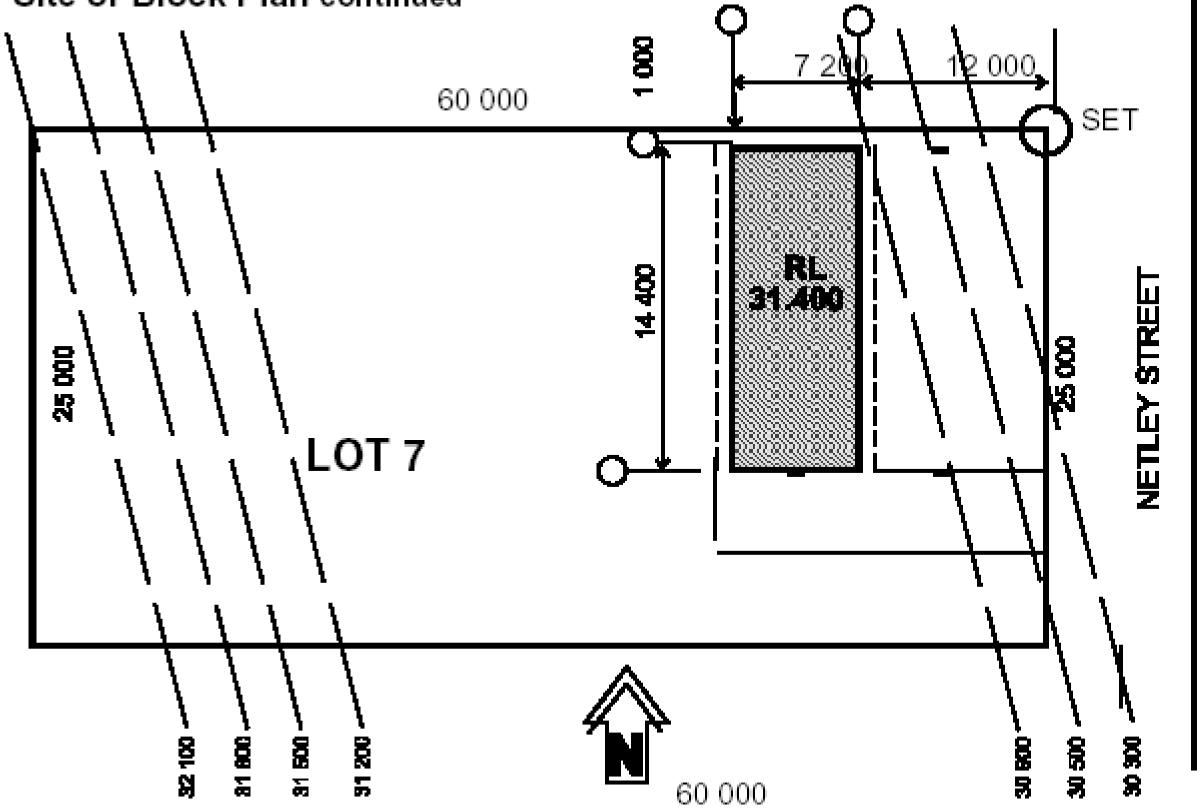
Plan 2: Site plan

Site plans are drawn to show the location of a building on the land that it will be built on. It is an overhead view of the construction site and the building as it sits in reference to the boundries of the lot. Site plans should outline location of utility services, retaining walls, setback requirements, easements, fences, location of driveways and walkways, and sometimes even topographical data that specifies the slope of the terrain.



A Site or Block Plan is usually drawn at 1:500 and gives the following information.

Site or Block Plan continued



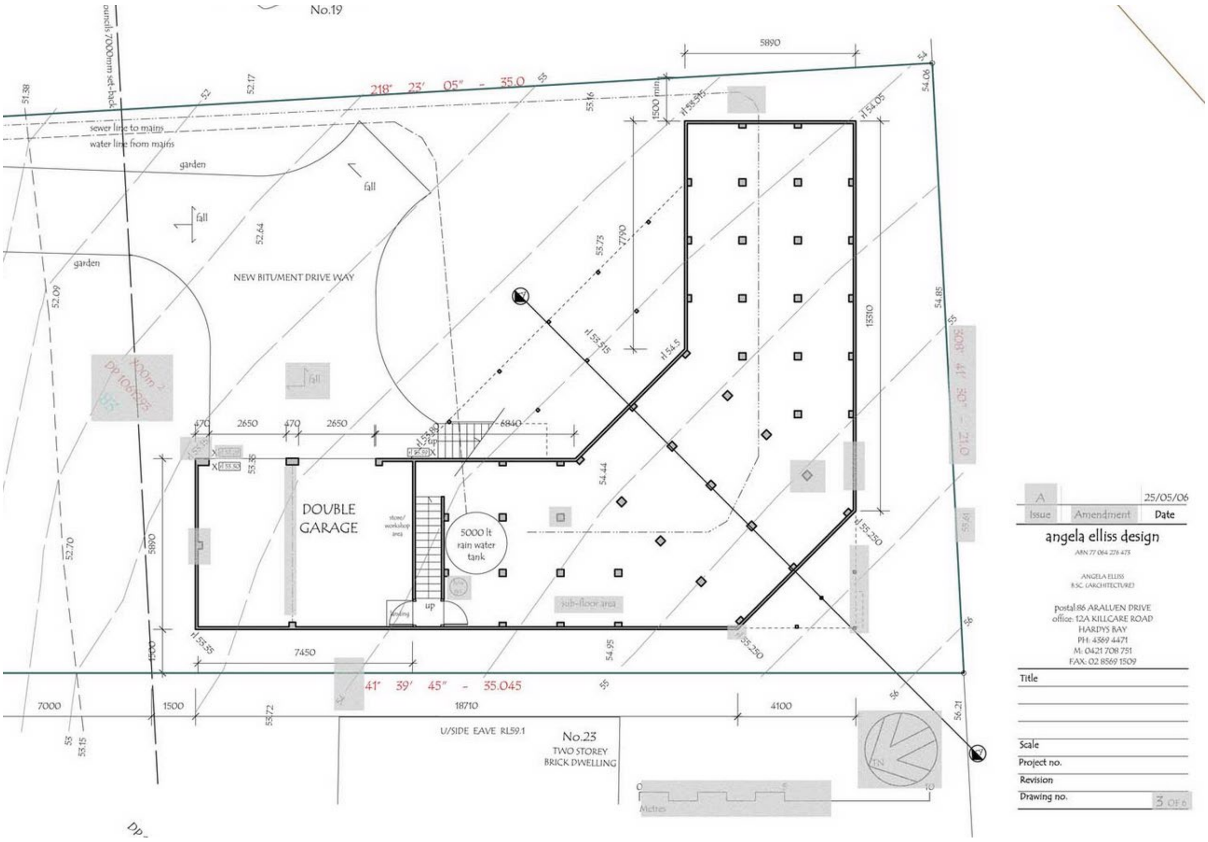
SITE OR BLOCK PLAN - SCALE 1:500
(NOTE: This drawing is not drawn to scale.)

Features to look for on plans.

- A datum is a reference point of known or assumed height to which all other site levels will refer.
- Plan page number, client's name, project address, scales used, name and reference numbers of draftsperson and the date the plans were drawn.
- Features that must be preserved e.g. trees, rocks, existing structures
- Contours may also be imposed on a plan or may be noted separately. These show the fall in the land, are usually related to the datum and usually spaced at 500mm horizontal intervals for a single building development, while still showing the north point.
- The term Reduced Level e.g. (RL 100.000) may also be seen. This may indicate finished floor, ceiling, eave and roof apex in relation to the datum
- Distance from the boundaries to the building's outer walls or "footprint" -mostly of interest for council and neighbours. Most councils have a code or specifications for the distances between the building and the side, front and rear boundaries. The distance from the front boundary to the building is referred to as the front building line.
- Driveways, stormwater drainage, paths, easements and right of carriage (right of use) may also be shown.

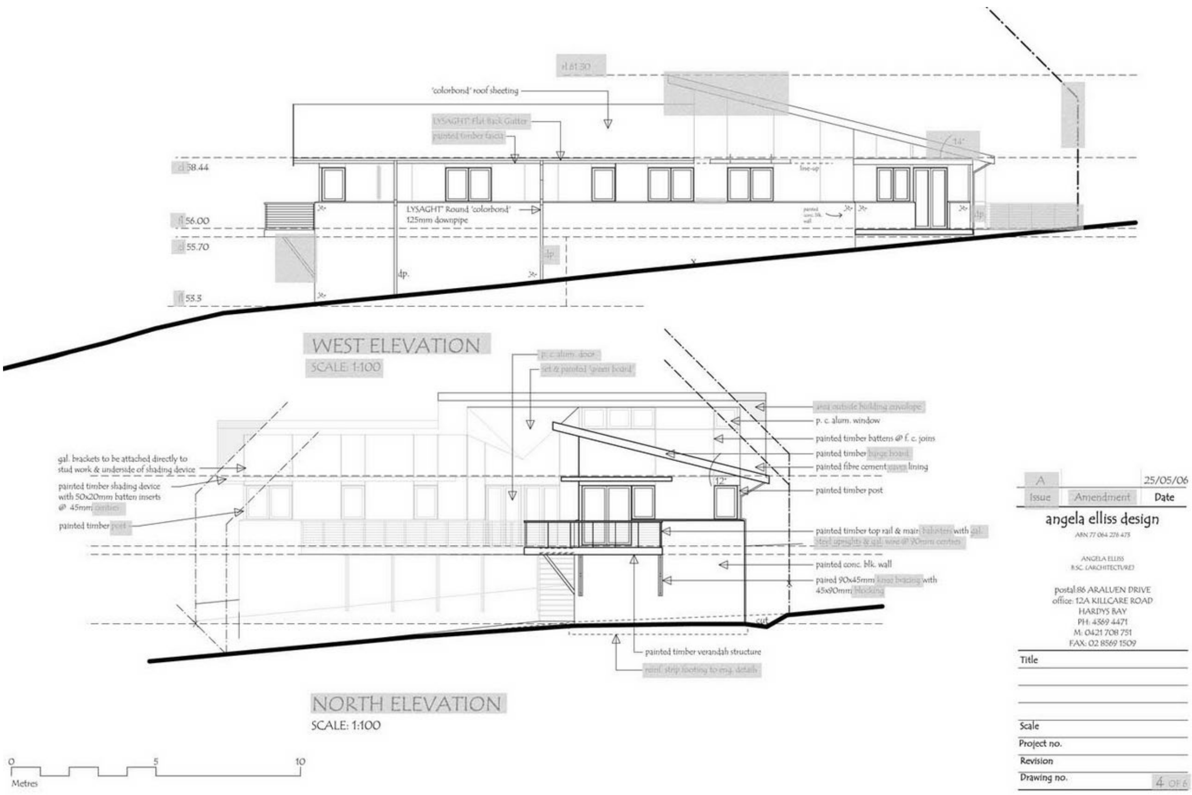
Plan 3: Sub-floor Plan

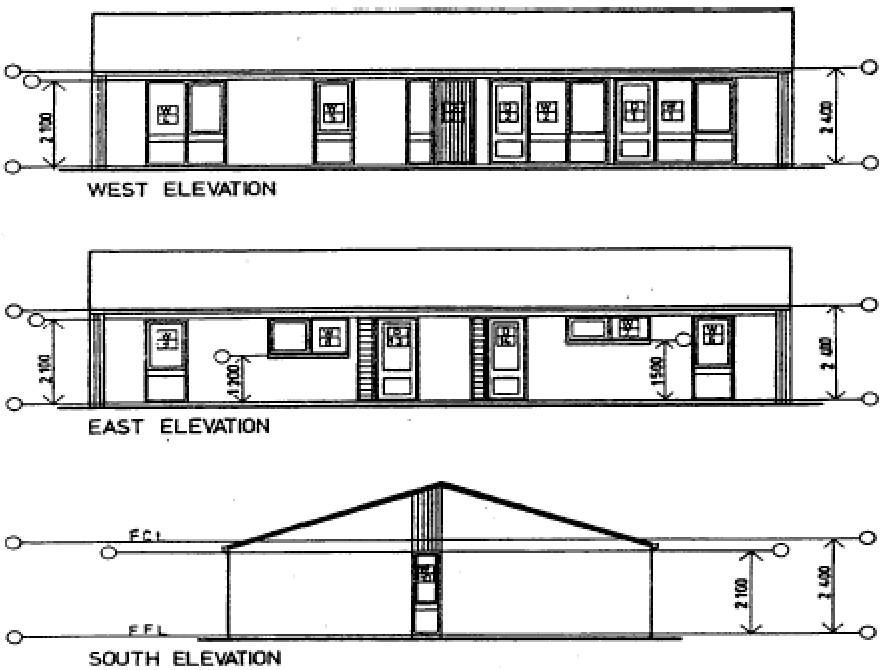
The sub-floor plan gives details of how this area will be constructed and how services will be arranged.



Plan 4: Elevations

Elevations are a non-perspective view of the house. These are drawn to scale so that measurements can be taken for any aspect necessary. Plans include front, rear and both side elevations. The elevations specify ridge heights, the positioning of the final fall of the land, exterior finishes, roof pitches, fence locations and other details that are necessary to give the house its exterior architectural styling.





EXAMPLES OF ELEVATION VIEWS - Drawn to scale and reduced

An elevation is a view you see when standing in front of that wall. It may be multi-storey or single-storey, usually drawn to a scale of 1:100. This scale can vary.

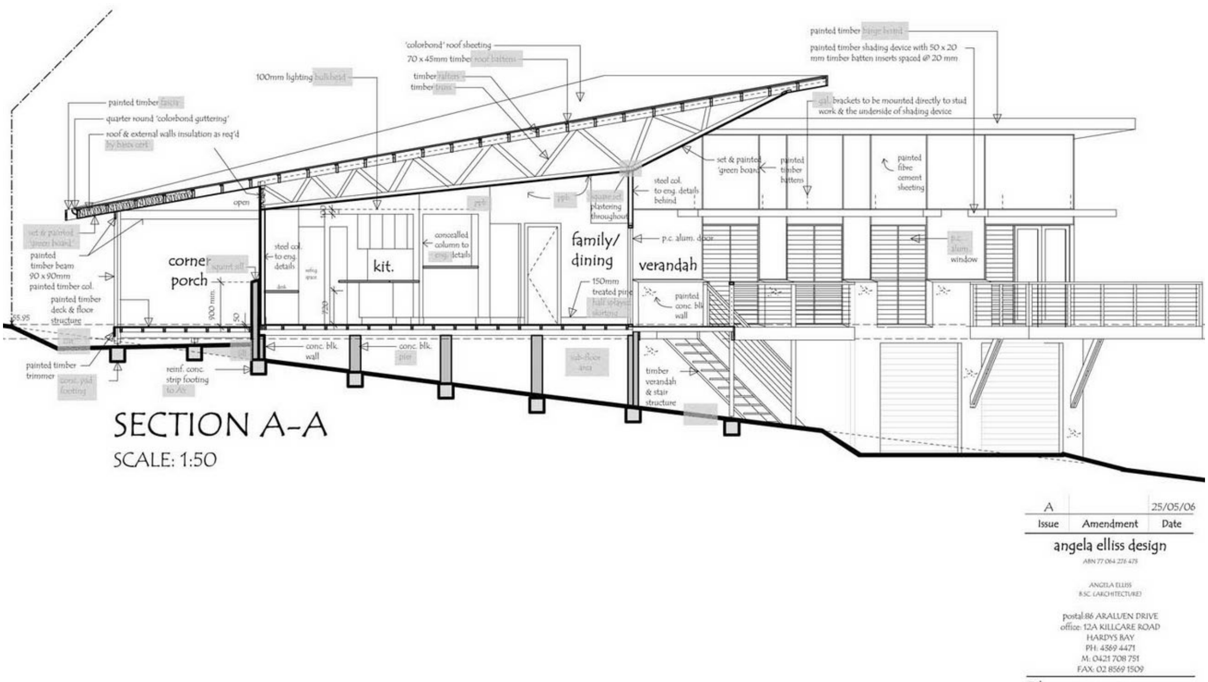
Most councils require an elevation from each side of the proposed development and the view is indicated by north, south, east or west - e.g. If the wall is on the west side of the house, it is the west elevation.

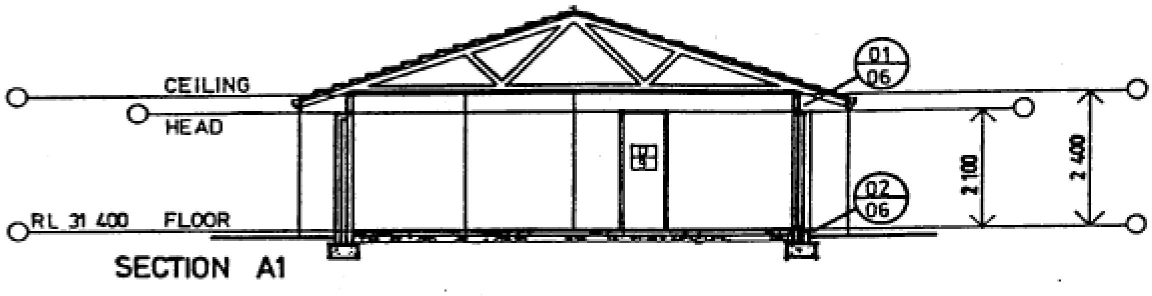
Elevations indicate:

- finish to external walls and;
- size of windows, doors and balconies.

Plan 5: Section

A section cuts through the dwelling and the location of this 'cut through' is noted on the floor plan. It describes how the building will be constructed and discusses how the internal finishes are to look. Sections are used because they explain certain conditions in more detail.





ELEVATION SECTION - Scale 1:100 (Reduced)

What is a section?

It is a vertical view (â€œsliceâ€?) through the building. The direction of section lines or arrows is usually shown on the plan to help interpret the sectional view.

Sections may be required to indicate:

- overall height of the building
- position of piers, beams, openings etc.
- floor to ceiling heights
- distance between finished floor and existing ground levels or proposed ground levels
- construction details
- scales same as plan.

Detailed Drawings

Detailed Drawings are used to illustrate the particular method of construction or finish required - e.g. structural steelwork, concrete work, brickwork. They are usually drawn at scales that are easy to read (1:20, 1:5) .

Specifications

Specifications set out the minimum standards or codes necessary to obtain relevant sizes for all structural components.Specifications may also detail the fixtures and fittings. It will not indicate utilities such as water or electricity.

A Title Block

A **Title Block** is a section of information on a plan. It shows:

- date drawn

- site address
- number of sheet (page) in relation to others
- name of sheet
- name of client
- builder's name
- scales used
- date of amendments
- draftsperson's name
- glossary of terms

NOTE:

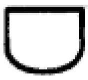
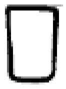
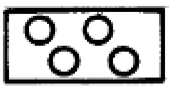
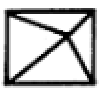
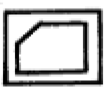
The Australian Architectural Standards details must be used to indicated items, dimensions, products and names on plans.

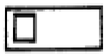
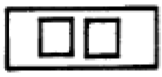
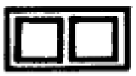
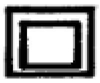
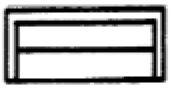
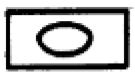
SECTION 1 - PROJECTIONS, STANDARDS & ABBREVIATIONS

Symbols

The ***Australian Architectural Standards*** details the Symbols that must be used in drawings.

These symbols represent various features on drawings. They are not necessarily drawn to scale. They can vary slightly from those shown as a result of the drafter or architect using a template.

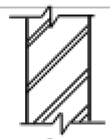
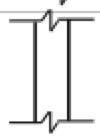
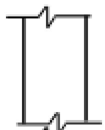
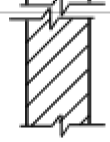
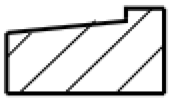
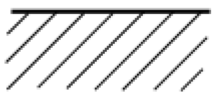
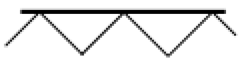
MEANING OF THE SYMBOL	THE SYMBOL
BASIN	
BIDET	
BATH	
DRINKING FOUNTAIN	
DRINKING TROUGH	
HOTPLATES	
SHOWER	
SHOWER BATH	

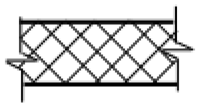
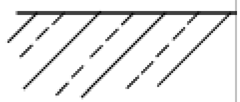
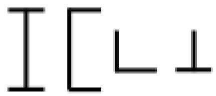
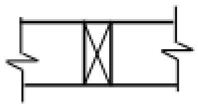
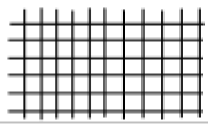
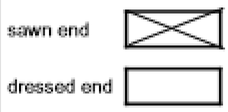
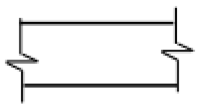
MEANING OF SYMBOL	THE SYMBOLS
SINK Single bowl Locate bowl as re-quired	
SINK Double bowl Locate bowls as required	
TUB Double	
TUB Single	
URINAL STALL	
VANITY BASIN	
WATER CLOSET	

SECTION 1 - PROJECTIONS, STANDARDS & ABBREVIATIONS

Hatching

Hatching is used to represent the material being sectioned. In many cases hatching is not possible because the drawing is too small. It is time consuming and should only be used when it assists in the understanding of the drawing detail. Colours have also been set in the standards, but are only used if rendered presentation drawings are been prepared.

MATERIAL	HATCHING
BRICKWORK	
CEMENT RENDER	
CONCRETE	
CONCRETE BLOCK	
CUT STONE MASONRY	
EARTH	
FILL	
GLASS	
HARDCORE	

MATERIAL	HATCHING
INSULATION	
PARTICLE BOARD	
ROCK	
STRUCTURAL STEEL	
STUD WALLS	
TILES	
TIMBER	
FIBROUS OR ACOUSTIC PLASTER	
HARD PLASTER OR PLASTER BOARD	

Abbreviations

Abbreviations are used to help keep drawings clear and easy to read, and to simplify notations on drawings. If abbreviations were always written out in full it would just clutter the drawing and make other information difficult to find and read.

There are many abbreviations, so not all of them are in the list below. Any abbreviations that you come across in drawings shown to you by your Trainer or during your on-site experiences should be recorded on the ***Additional Information*** page at the back of this booklet.

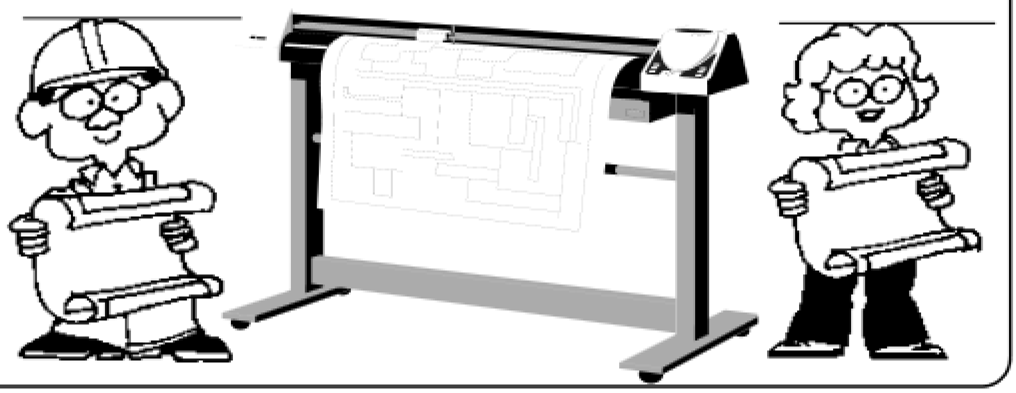
NOTE: Punctuation marks should not be added to abbreviations

Some of the more commonly used abbreviations are:

ACRYL	Acrylic
ACST	Acoustic
AL	Aluminium
AO	Access Opening
AP	Access Panel
APD	Agricultural Pipe Drain
AS	Australian Standard
ASB	Asbestos
ASPH	Asphalt
ASSD	Assumed Datum
B	Basin
BC	Bookcase
BD	Board
BIT	Bitumen
B/I	Built-In
BK	Brick
BLDG	Building
BM	Bench Mark
BN	Bull Nose
BPL	Baseplate
BT	Boundary Trap
BTH	Bath
BV	Brick Veneer
BWK	Brickwork
CAB	Cabinet
CAN	Canopy
CAV	Cavity
CB	Concrete Block
CD	Clothes Drier
CF	Concrete Floor
CG	Clear Glass
CJ	Ceiling Joist
CORR	Corrugated
CPD	Cupboard
CR	Cement Render
CRS	Cold Rolled Steel
CW	Cold Water
CWT	Cold Water Tank
DG	Double Glazing
DH	Double Hung
DPC	Damp Proof Course
DSB	Distribn. Switch Board
DW	Dishwasher
EFF	Effluent
EJ	Expansion Joint
FA	Fire Alarm
FD	Fire Detector
FE	Fire Extinguisher
FFL	Finished Floor Level
FH	Fire Hydrant
FHR	Fire Hose Reel
FPBD	Fibrous Plaster Board
FWS	Fire Water Service
GIT	Grease Interceptor Trap
GM	Gas Meter
GPO	General Purpose Outlet
HBD	Hardboard
HTR	Heater
HW	Hot Water Unit
HWD	Hardwood

ABBREVIATIONS continued

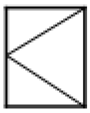
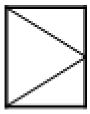
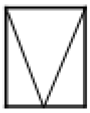
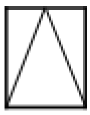
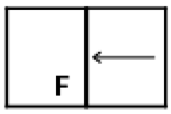
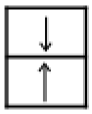
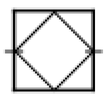
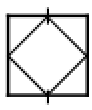
INSUL	Insulation	SBD	Strawboard
LIN	Linen Cupboard	SC	Stop Cock
LVR	Louvre	SCP	Satin Chrome Plated
M	Meter	SD	Sewer Drain
MSB	Main Switch Board	SD	Sliding Door
MSRY	Masonry	SHR	Shower
N	North	SP	Standpipe
NGL	Natural Ground Level	ST	Stop Tap
O	Oven	SV	Safety Valve
PBD	Plasterboard	SV	Stop Valve
PC	Pre Cast	SVP	Sewer Vent Pipe
PED	Pedestal	SWD	Storm Water Drain
PF	Paling Fence	SWD	Softwood
PG	Plate Glass	SWL	Safe Working Load
PLY	Plywood	TC	Terra Cotta
P & R	Post & Rail	TEL	Telephone
PREFAB	Prefabrication	TRZO	Terrazzo
PTN	Partition	TS	Time Switch
QUAD	Quadrant Moulding	TV	Television
REFRIG	Refrigerator	U/G	Underground
RHS	Rolled Hollow Section	UR	Urinal
RS	Roller Shutter	UTIL	Utility
RSJ	Rolled Steel Joist	VCP	Vitrified Clay Pipe
RWP	Rain Water Pipe	VENT	Ventilator
RWT	Rain Water Tank	VP	Vent Pipe
		VT	Vinyl Tiles
		WBD	Wallboard
		WI	Wrought Iron
		WM	Washing Machine

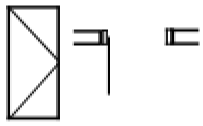
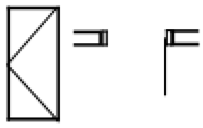
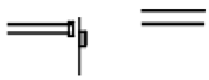
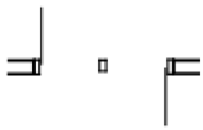
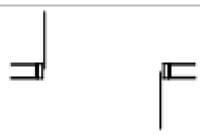


SECTION 1 - PROJECTIONS, STANDARDS & ABBREVIATIONS

Architectural conventions

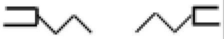
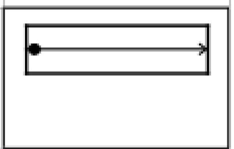
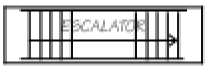
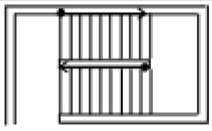
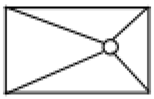
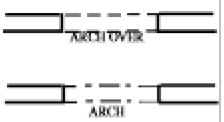
Architects and drafters use a number of simplified representations of features found in buildings when they produce the plans builders need. These representations are called ***conventions***.

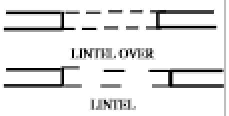
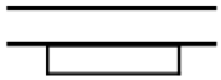
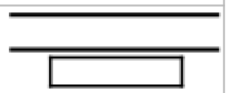
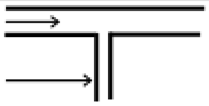
FEATURE	CONVENTION
WINDOW Right Side Hinged	
WINDOW Left Side Hinged	
WINDOW Top Hinged	
WINDOW Bottom Hinged	
WINDOW Horizontal Sliding With Fixed Sash	
WINDOW Vertical Sliding	
WINDOW Side Pivots	
WINDOW Top & Bottom Pivots	
WINDOW Plan View	

FEATURE	CONVENTION
SINGLE DOOR Left Swinging 90	
SINGLE DOOR Right Swinging 90	
SINGLE DOOR 180 Swinging	
SINGLE DOOR Double Acting	
PAIR OF DOORS Double Acting	
IN & OUT DOORS With Mullion	
IN & OUT DOORS Without Mullion	
SLIDING DOOR Into Cavity	
SLIDING DOOR On Face of Wall	

SECTION 1 - PROJECTIONS, STANDARDS & ABBREVIATIONS

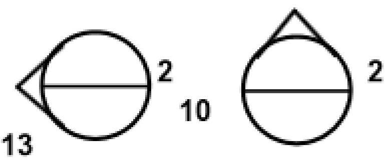
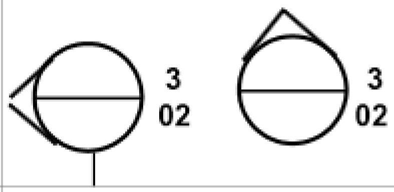
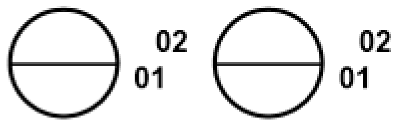
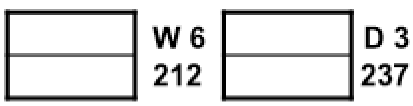
Architectural Conventions continued

FEATURE	CONVENTION
DOOR Vertical Sliding	
DOORS Folding Centre Track	
DOORS Folding Side Track	
DOORS Concertina	
SHOWER CURTAIN Draperies etc	
RAMP Arrow up	
ESCALATOR Arrow Up	
STAIRS Arrows Up	
FLOOR SLOPE With Floor Drain	
ARCHWAYS	

FEATURE	CONVENTION
OPENINGS Opening from floor to of wall or partition	
LINTELS	
OTHER OPENINGS All other openings not included above	
ACCESS HATCH In Floor	
ACCESS HATCH In Ceiling	
SKYLIGHT In Ceiling	
FURNITURE Recessed	
FURNITURE Wall Mounted	
FURNITURE Free Standing	
WALL - Cavity WALL - Single	

Architectural conventions continued

As there may be many sheets of drawings to a set of plans, and on these sheets there may be information in relation to window and door types, the following architectural conventions are recommended. These are the Australian Standards, however it must be understood that slight, in-house, variations on these recommendations are often used by architects and drafters.

FEATURE	CONVENTION
SPECIAL AREA REFERENCE Drawing or Detail Number ——— Sheet Number	
ELEVATION REFERENCE (« See note below) Elevation Sequence Number ——— Sheet Number	
SECTION REFERENCE NUMBER (« See note below) Section Sequence Number ——— Sheet Number	
DETAIL REFERENCE Detail Sequence Number ——— Sheet Number	
WINDOW AND DOOR REFERENCE Window or Door Reference ——— Window or Door Number	
NOTE: In items («) above, if there are several building blocks, indicate first the block, then the reference number, eg. for Block 86, Elevation 2, Sheet Number 4.	

Construction lines, Perpendiculars and Arcs

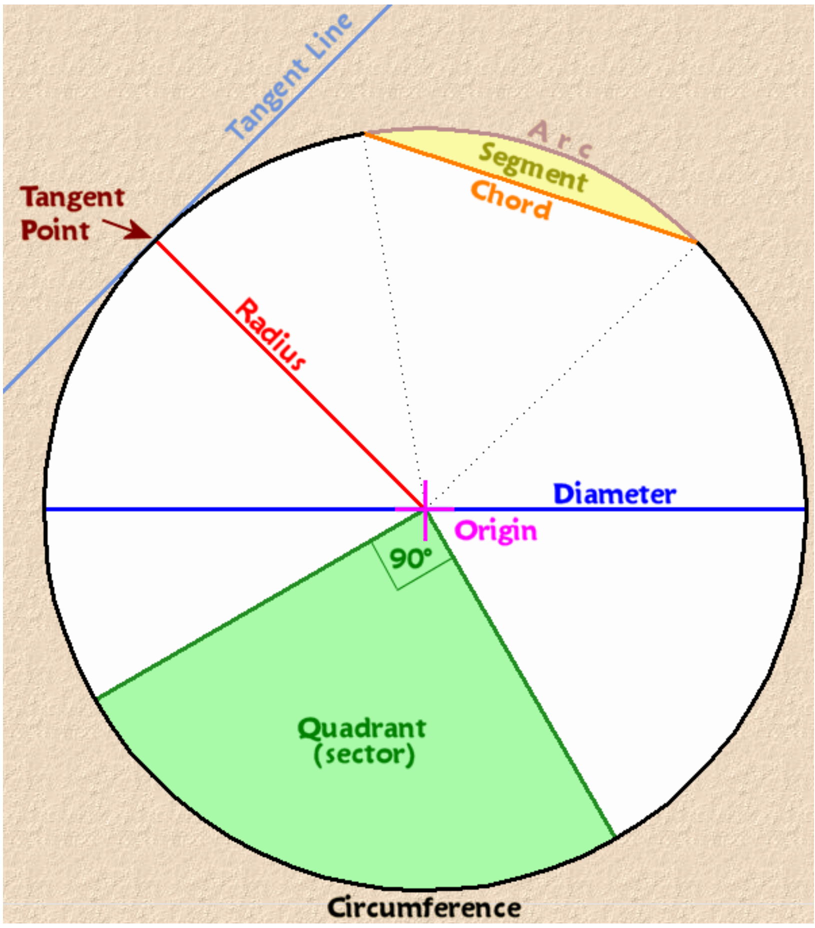
All paving and landscape projects need to be 'set out' - this is the process of using geometry to establish lines, levels, curves and arcs, as well as positioning other features in relation to a given point, typically a house, or other building.

Geometry

Paving and streetmasonry can, at times, seem littered with references to barely-remembered geometric terminology, but most of it is comparatively simple and based around the geometry of circles and right-angled triangles.

Much of that geometry is most easily explained using kerbs as an example, as they are often the closest physical manifestation we have to the geometry created by a designer, specifier or architect. However, the same geometric terms and relationships apply to all aspects of paving, streetmasonry and hardscapes. Just take a look at the work done in preparing a flagstone fan radius, if further proof is needed!

This page sets out to define some of the most commonly encountered terms.



Circle and Arc Definitions

Origin

The centre of a circle. The point from which a radius is swung. All points on a circle's outer edge (circumference) are the same distance from the origin.

Radius

This has to be the most commonly used term in streetmasonry, which tends to focus on kerblines of a given radius and fancy set-outs, but it is also used with more simple paving projects.

The radius is the distance from the centre of a circle (the origin) to any point on its outside edge (the circumference)

The plural is sometimes referred to as radii (ray-di-eye)

A physical line following the radius, from the origin out to the circumference, may also be known as a radial

The kerbline follows the circumference of a circle and each kerb unit is the same distance from the shown as pink radial lines

Diameter

The diameter is the span across a full circle, from one side to the other passing through the origin.

Any line touching the circle circumference in two places and passing through the origin MUST be a diameter.

The diameter of a circle is always equal to two radii

The 'step' running across this feature kerb circle i diameter, as it touches both sides of the circle an through the origin (lighting column)

Tangent

A line or other geometrical construction (could be another circle, an arc or and ellipse) is said to be a tangent, or is tangential to, when it meets or 'kisses' a circle or arc at only one point.

Tangent Point

The point where a tangent meets or 'kisses' the circle

This term is most commonly used to describe the point on a kerbline where a straight line becomes a curve. The kerbs of the tangent line will be straight units, but once past the tangent point, the kerbs may be radius units or be laid to an arc.

Arc

An arc is any part of the circumference of a circle.

It may be relatively short and shallow, or it could be almost a full circle.

Bends and curves are formed using one or more arcs

An s-curve formed by linking an internal and exte by a short length of straight

Quadrant

A quadrant is the area under an arc that is exactly one-quarter of a full circle.

In classical geometry, the area under an arc is known as a 'sector'. A quadrant is a special type of sector.

The term 'Quadrant' may refer to the arc or to the sector enclosed by two radial lines set at 90°

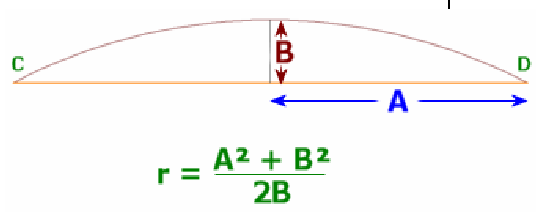
Single-piece quarter-circle kerbs are often known as "Quadrants" or "Cheeses"

Chord

Whereas a tangent only touches the circumference of a circle or arc at one point, a chord touches at two points.

When such a line passes through the origin, it is a diameter, but any other line touching the same circle or arc at two points is a chord.

Chords can be very useful when it's necessary to determine the radius of an arc from a single kerb or short section of arc...see drawing opposite.



To find radius (r) of arc...

Create a chord, here labelled C - D, and measure i
length.
Divide by 2 and refer to as "A"

Measure perpendicular distance from arc to mid-
chord. Refer to as "B"

Add together the square of A plus the square of B

Divide the result by 2B (twice what was measured
perpendicular)

Segment

As previously described, the area of a circle bounded by an arc and two radii is referred to as a sector. Similarly, the area bounded by an arc and a chord is known as a segment.

Segments aren't widely used in paving and streetmasonry but are included here for completeness.

Circle and Arc Equations

Calculating circumference

The circumference of a circle is calculated using Pi (Π) which can be as a fraction, 22/7, or as a decimal nu
roughly 3.142

C = 2 x Π x r

Where C = circumference
Π = 3.142
r = radius of the circle

So: a circle with a measured radius of, say, 2.4m has a circumference of...

2 x 3.142 x 2.4 = 15.08m

For the length of an arc, the calculated circumference is simply multiplied by the ratio of the angle of the
360°...

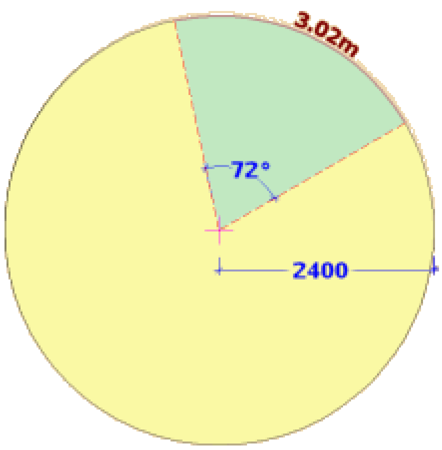
arc = 2 x Π x r x (∠ ÷ 360)

Where C = circumference
Π = 3.142
r = radius of the circle
∠ = angle of arc

So: in our 2.4m radius circle described above, an arc of 72° has a circumference of...

2 x 3.142 x 2.4 x (72 ÷ 360)

15.08 x 0.2 = 3.02m



Calculating area

Generally speaking, the ability to calculate the area of a circle or arc is more useful to the typical paving contractor than circumference, and once again, the calculation depends on that magic figure, Π

$A = \Pi \times r^2$

Where A = Area
Π = 3.142
r = radius of the circle

So: the now-familiar circle with a measured radius of 2.4m has an area of...

3.142 x (2.4 x 2.4)

3.142 x 5.76 = 18.1m^2

For the area under an arc (more correctly known as a 'sector'), the calculated whole circle area is simply multiplied by the ratio of the angle of the arc over 360°...

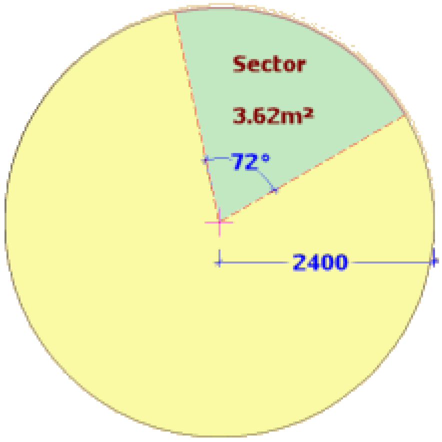
$A = \Pi \times r^2 : (\angle \div 360)$

Where A = Area of sector
Π = 3.142
r = radius of the circle
∠ = angle of arc

So: in our 2.4m radius circle described above, an arc of 72° has a sector with an area of...

3.142 x (2.4 x 2.4) x (72 ÷ 360)

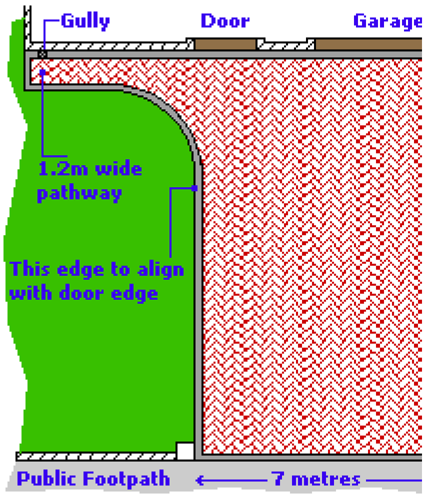
3.142 x 5.76 x 0.2 = 3.62m²



On larger projects, automatic levels, theodolites, laser levels and even GPS are used to assist in the setting out, but there are some basic setting-out skills that require nothing more technical than a string line, an accurate spirit level, a tape measure, a handful of marker pegs, preferably 12mm steel road pins, and occasionally, a calculator, all of which should be readily available.

To illustrate some of these basic principles used in setting out, the plan for a typical driveway shown opposite will be used as a case study. This is a fairly common layout scenario for a block paved driveway.

The brief is to create a drive 7 metres wide, which is to align with the left hand edge of the front door, with a curved sweep on the right hand side to accommodate the double width garage and a smaller curve on the left hand side to tie in with a 1.2m wide pathway along the front of the property.



The drainage of the pavement is catered for by existing surface water gullies collecting from downspouts located on both front corners of the property. The general level of the site is flat, with no more than 50mm of fall from the paving level at the front of the house to the threshold with the public footpath.

Fastening string lines

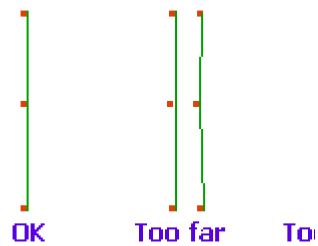
Much reference is made in these pages to the use of a taut string line as an aid to line and level. The string line is fastened onto steel marker pins using two standard 'knots'. In the photos, a length of thick, red washing line has been used to make the line more visible, but in practice, a nylon or fine cotton string about 2-3mm in diameter, is used.

The string line needs to start somewhere, and so a 'double loop' is used to fix one end of the line to the first pin. The double loop is twisted as shown in the picture opposite, and then placed over the starter pin, and adjusted to the required level.

Once the string line is securely fastened onto the first pin, it is paid out to the next pin and fastened to that by means of a 'half hitch', as shown in the photo opposite. A half hitch such as this depends on tension from the preceding length of line to hold itself in place, and so, in the picture, the line is feeding in from the left hand side, pulled tight and then brought around the pin and under itself, where the tension then holds the loop in place.

These half hitches are used on subsequent pins until the work in hand is completely set out. As has been mentioned, curves and arcs may need pins to carry the line at relatively short intervals; with straight sections the pins should be positioned no more than 10m apart, provided that the string line can be sufficiently tensioned to prevent any sag. If a line is sagging, it gives a wrong guide for level, and so it may be necessary to use pins at, say, 5m intervals.

When setting out a straight line with intermediate pins, the start and end pins are positioned first, a string line pulled tight between the two, and then the intermediate pins established so that they are just touching the taut string line. If the pin is not touching the line, or if the line is deflected by the pin position, this will lead to a 'dog-leg', ie a kink, in the supposedly straight line.



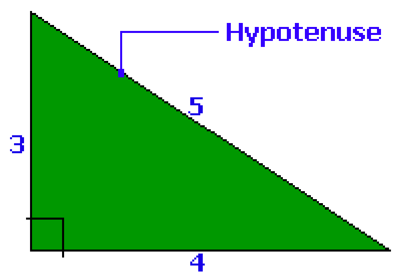
Setting intermediate pins to a straight line

On long straights, the intermediate pins are established by halving the distance between two existing pins. So, for example, on a 100 metre run, the start pin is established at 0 metres, and the end pin at 100 metres. The first intermediate pin is established at 50 metres, checked for accuracy and the string fastened to it, usually with a half-hitch. Next, two further intermediates would be established at 25 metres and 75 metres, and again, the string line is fastened to them once their position has been checked. This routine continues, with intermediates being established at 12.5 metres, 37.5m, 62.5m and 87.5m, and then possibly at 6m, 18m, 31m, 43m, 56m, 69m, 81m and 94m. Once all intermediates are in place, the alignment of the string line should be visually checked for accuracy by sighting along the line.

Setting up a straight string line

Setting out a perpendicular

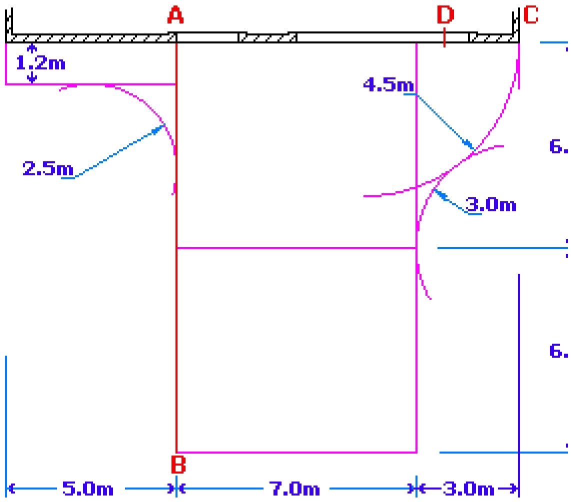
A perpendicular is a line that is at exactly 90° to a base line. They are essential to accurate setting out, and are constructed using one of the fundamental principals of building work, the 3-4-5 triangle. From Pythagoras' theorem, we can establish that any triangle that has side lengths in the ratio of 3:4:5 *must* be a right angled triangle.



It doesn't matter if the side lengths are 3m, 4m and 5m, or 60 feet, 80 feet and 100 feet - as long as the 3:4:5 ratio is maintained, the triangle will have a right angle. With longer side lengths, however, accuracy of measurement can be become a problem, so we try to use a triangle with a maximum hypotenuse length of around 15 metres, although this is not always possible. With larger triangles, we will perform more check measurements to ensure accuracy.

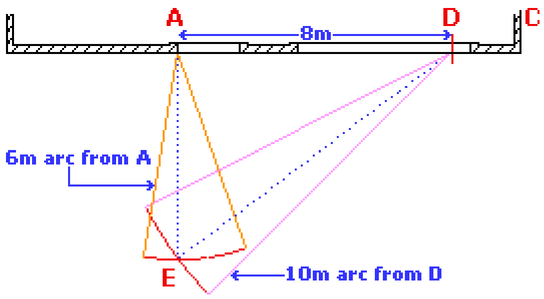
Putting this knowledge to practical use, we can see from the construction plan for the driveway that the shape of the drive is constructed from a series of rectangles and arcs. The most important line to be set-out is the left-hand edge of the driveway, line A-B marked in red on the drawing, which is perpendicular to the front of the house, and is aligned with the left-hand edge of the doorway. To establish this perpendicular, we use a 3-4-5 triangle.

The dimensions on the drawing states that the distance from the left hand edge of the front doorway (A), to the right hand corner of the property (C) is 7m + 3m = 10m. However, most landscape plans are drawn at a scale of 1:100 or greater, and will usually have an accuracy of around ±75mm. For our right angled triangle we need to be as exact as possible with our measurements to ensure we get a true right angle at 90°, and not at 88° or 91°, so a measure is made along the front of the house and a distance of 8m is marked with crayon or chalk at point D, just in front of the garage door.



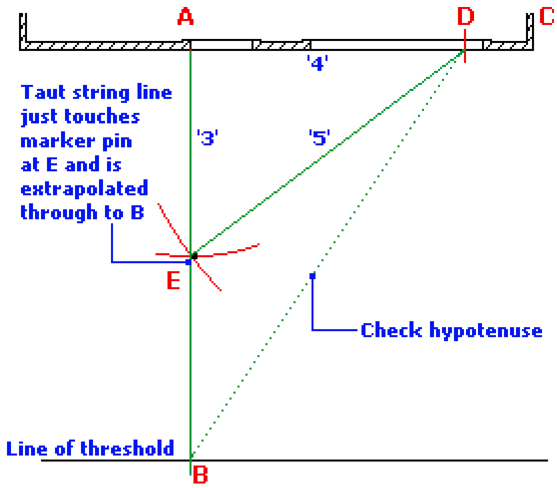
8m has been chosen as the length of the base line A-C because it is a multiple of 4, the largest side of the 3-4-5 triangle other than the hypotenuse. The base line is regarded as true, and so the longest available edge, ie, the '4' always goes along the base line.

From these two fixed points, A and D, we now mark out two arcs. These can be scratches on the ground, sand lines, spray paint, crayon or anything that can make a mark. From Point A we mark out a 6m arc, ie, the '3' side of the 3-4-5 triangle, and from Point D we mark out a 10m arc, ie, the '5', the hypotenuse. Where these two arcs intersect, Point E, marks the apex of a 3-4-5 triangle.



If you have two tape measures, these can be used in place of arc marking, provided that you can anchor the tapes ends securely at points A and D. Pull the two tapes towards point E, and where the 6m mark on the tape from A meets the 10m mark on the tape from B, is exactly point E. Drive in a steel pin to mark the point.

If we now draw a line from point A to point E, we have a line that is perpendicular to the front of the property, and aligned as required with the left hand edge of the doorway. A stake or steel pin is knocked into the ground a point E. A string line is securely fastened to point A, and pulled tight, past the marker pin at E and extended all the way to the threshold of the drive. As long as the line is just touching the marker pin at E, the perpendicular line created from the 3-4-5 triangle is extrapolated and point B can be established and marked with a steel pin.



The accuracy of the perpendicular can be checked by measuring the hypotenuse B-D. We know that A-D = 8m, and we can measure that A-B = 12m. Pythagoras tells us that the hypotenuse, B-D is equal to the square root (SQRT) of $(A\text{-}D)^2 + (A\text{-}B)^2$

B-D = SQRT $(8^2 + 12^2)$

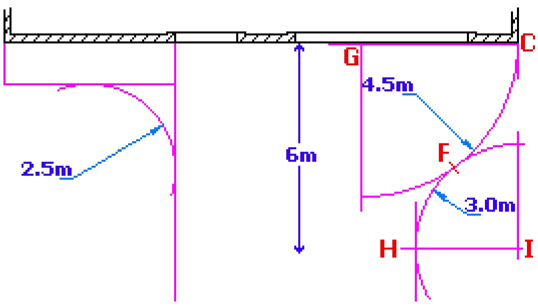
B-D = SQRT (64+144) = SQRT 208 = 14.42 metres

The distance from point B to point D is measured and checked against the calculation for accuracy. In this example, a measurement of between 14.40m and 14.45m will be satisfactory as a check. If the measure is outside this tolerance, check the perpendicular again, setting out an alternative 3-4-5 triangle from the base line, if necessary.

Setting out arcs and curves

Arcs and curves are much simpler to set out. Any arc has 3 important points, namely the start tangent point, the end tangent point and the origin. A tangent point is the point where an arc just touches or intersects a straight line or other arc. In the drawing below, Points C, F, and H are all tangent points.

Referring back to our construction plan, we can see that two arcs are used on the right hand side of the driveway to make an 'S' curve. The 4.5m arc has its origin at G, and a tangent point with the building at C. The 3m arc has its origin at I, with a tangent point at H, where it meets the line that continues towards the public



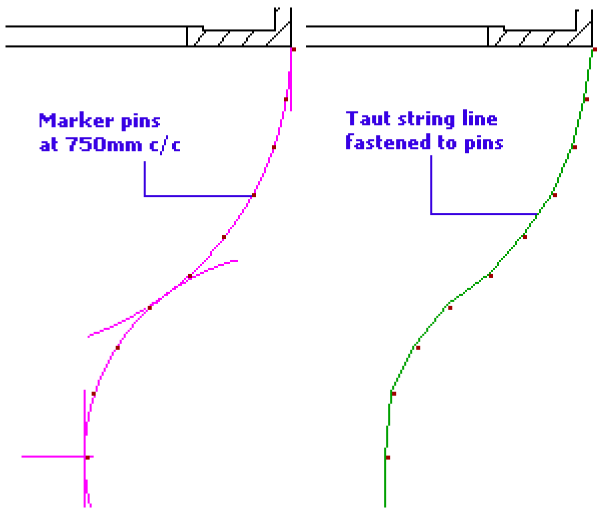
footpath. Where these two arcs 'kiss', at point F, is also a tangent point, common to both arcs.

It should be noted that these two arcs are very simple, in that they are orthogonal, ie, their origins and major tangent points coincide with other construction lines that are 'square', ie true perpendiculars or parallels to the base line of the front of the house. In some situations, the origin of an arc might be inaccessible, for example, it could lie within the building itself, or be obscured by trees. In such cases, accurate setting out of arcs can be achieved by the use of chords (straight lines connecting two known points on an arc), or 'inverse arcs'. This is dealt with on the Setting Out Obstructed Arcs page.

To establish the 4.5m arc, a measurement is made along the face of the building, and the origin marked at 4.5m from C, ie at point G. The tape measure can now be anchored at point G, and used to scribe out the arc by swinging it around, from C towards H, marking in spray paint or similar.

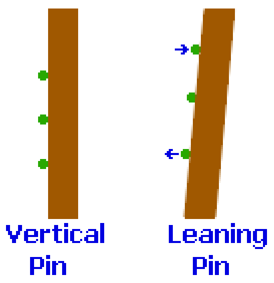
Establishing the 3m arc is a little more tricky. We can see that its origin, I, is located on a perpendicular from the building, aligned with the corner, C, and is 6 metres from the base line. Perpendiculars can be constructed, as detailed above, to locate the exact position of its origin, I, the tape then anchored at I and the resulting arc scribed in the same manner as the 4.5m arc. If all goes according to plan, the two arcs will 'kiss' at point F - the common tangent point.

All that remains now, is to drive in marker pins at regular intervals along the arcs. The separation between marker pins will depend upon the radius of the arc. The larger the arc, the greater can be the separation between two marker pins. For these two arcs with radii of less than 5 metres, we would typically use marker pins at 600-900mm separation.



On the plan opposite, the marker pins have been positioned at 750mm centre to centre (c/c) along the arcs. Once in position, a taut string line can be fastened to the pins to create a line guide for the laying of the arcs.

Using the two basic methods outlined above, it is now possible to set out the whole driveway with marker pins and a taut string line. However, this only gives us a line guide, a guide to the shape of the driveway. Next, we have to establish levels, to ensure that the driveway is sloping (falling) in the right direction to drain away any surface water. The height of the taut string line above ground level is adjusted at the marker pins to give us a guide to both line and level.



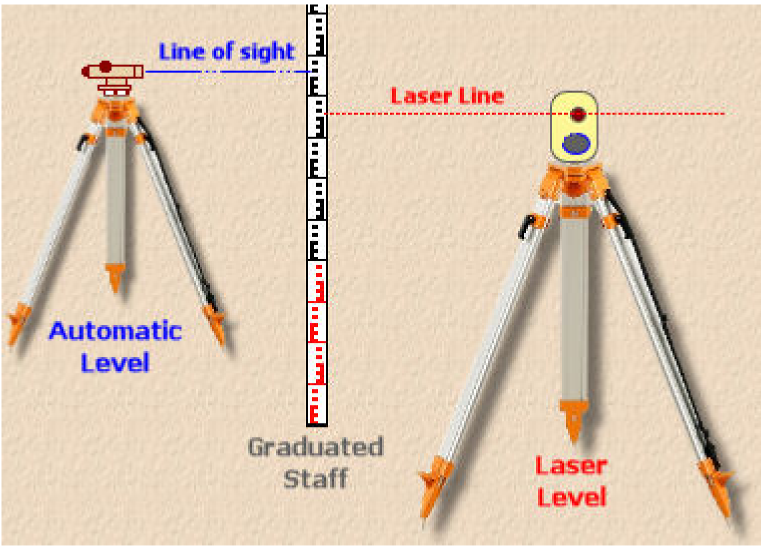
It is essential for accuracy that the pins are driven into the ground deep enough to be secure. They must be absolutely plumb, ie, vertical, otherwise, when the string line level is adjusted up or down the pin, the position is amended as well as the height, causing an error in the layout.

As can be seen in the diagram opposite, which is a cross-sectional view of the line, in green, and the pin, brown, when the pin is vertical, moving the line level up or down the pin makes no difference to position, whereas on the leaning pin, adjusting the line level results in the line position being displaced to the right or the left.

Automatic and Laser Levels

Builders and the better paving contractors will normally have an automatic (or 'dumpy') level to assist them in the setting of site levels. The more up-to-date amongst them may even have a laser level which have become cheaper and more readily available over the past few years.

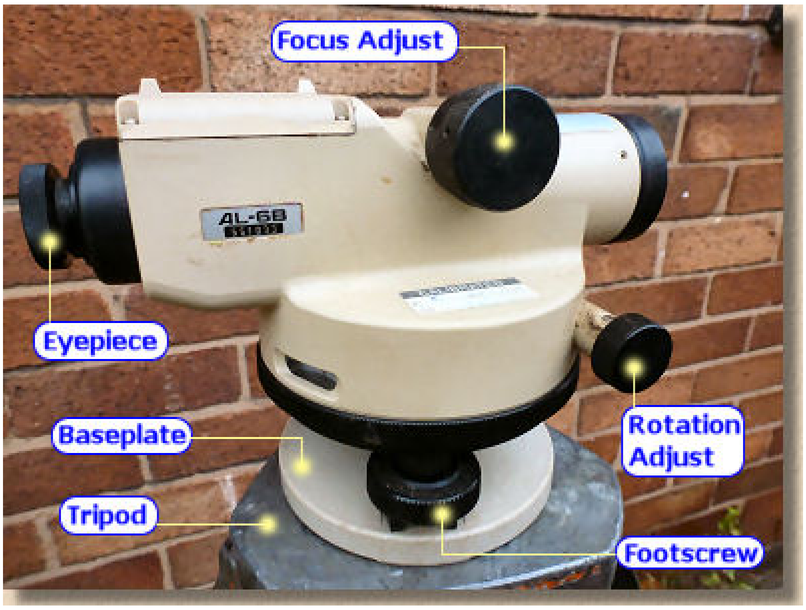
Both work on the same principle - that the 'kit' is set up in such a way that it defines a horizontal plane at a known height around 360° from which accurate measurements can be taken to establish point levels.



Although both automatic and laser levels could, in theory, be set-up on any stable platform (a bale of blocks, for example) it's muich better to use a tripod which can be positioned to ensure that it is simultaneously out of the way but that all points that may require levels to be established are visible.

Automatic Levels

An automatic level uses line of sight, albeit enhanced somewhat via the telescope, while a laser level emits a barely visible beam which is picked up by a detector. Both also rely on a graduated staff to measure the difference between the level plane and the point to be established.



As mentioned, the 'kit' is usually mounted on a tripod. Autmatic levels have some adjustment mechanism, most commonly a set of three adjustable screw-feet that allows the 'kit' to be set to true horizontal. The better laser levels are self-levelling, so automagically adjust the mechanism internally to ensure a horizontal plane.

The most common system for checking horizontality on automatic levels is a circular bubble tube. The foot-screws of the unit are adjusted until the bubble is centred within the bubble tube.

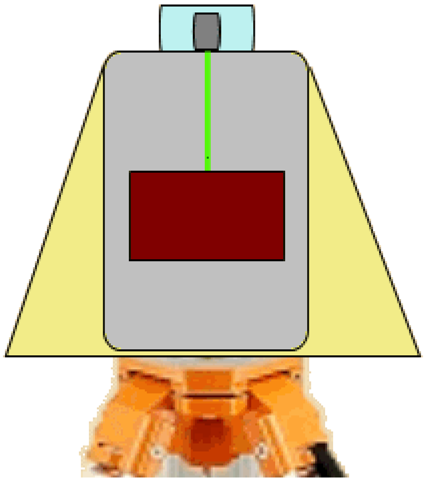
Different automatic and laser levels have differing degrees of accuracy. The bubble-set kit is usually taken as accurate to with 10 minutes (one-sixth of a degree; there are 60 minutes to one degree) and should be accurate enough for most site groundworks, landscaping and paving jobs.

There are more accurate levels available for exacting work where precision is vital, but, of course, they cost a lot more.

Centering the level-bubble on an automatic level

Laser Levels

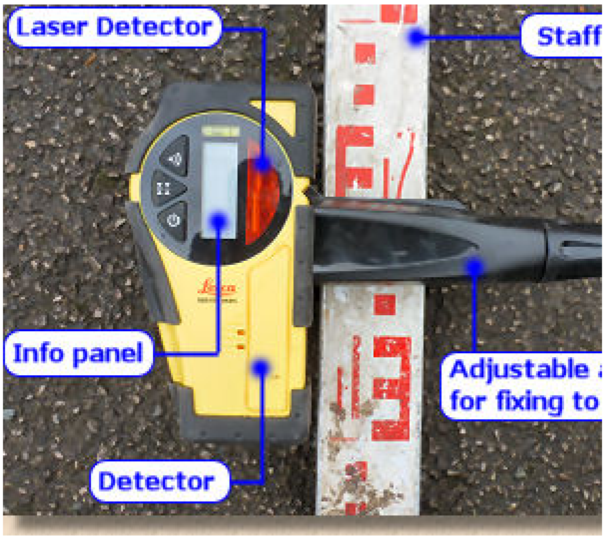
Laser levels work by generating a laser beam inside a protective housing, up to a spinning floating mirror which sends out the laser light over a reasonable distance (100-300m or so) as a truly horizontal beam.



Key features of a laser level

The laser beam is all-but invisible to the human eye, although special glasses can be work to make it more visible. However, this is of no consequence because rather than relying on sight, a leaser level uses a special detector which is attached to a standard graduated staff.

The detector is moved up and down the staff until the audible signal indicates it is at the precise height of the laser beam. Most detectors emit a series of beeps that get faster and faster as the detector is approaches the height of the laser beam. The sound changes to a continuous beep when at the exact level to detect the laser.



Setting up a laser level Laser Receiver attached to graduated staff

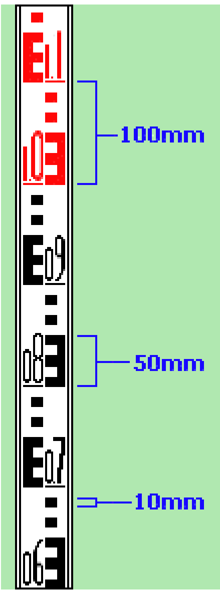
Setting-up a Station

The level unit is set-up in a position which gives a clear view of all points to be levelled, or as many as is feasible under site conditions.

Each position where the level is set-up is referred to as a 'station', and stations may be marked for future reference by means of a timber peg, steel pin, brass tag or paint mark as befits the conditions.

Marking of stations in this way allows levels and angles to be checked at a later date if a discrepancy is found.

Staffs, Benchmarks and Datums



Graduations on staff

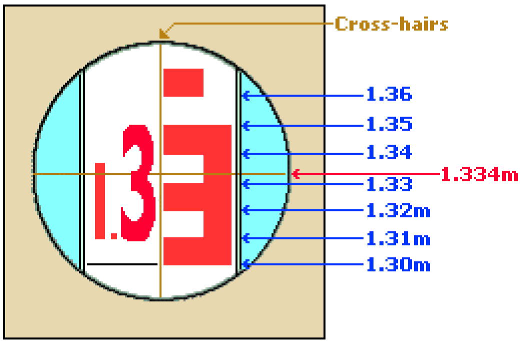
Once the surveying station is established, the relative height of the viewing or laser plane needs to be determined. This is done by taking a measurement at a point which has a known level. This point is called a 'Benchmark' (BM).

A Benchmark may be a known level, taken from a survey map or other official source, and given as a height in metres Above Ordnance Datum (AOD), which is usually taken as sea-level.

Levels established from this Benchmark to aid levelling elsewhere on the site are known Temporary Benchmarks (TBM).

For smaller projects, though, the absolute height AOD is of little relevance; what matters are the spot heights *relative* to a given point. For paving projects around the home, this given point will usually be floor level (FL) of the property, although it can be any fixed point whose height relationship with the works is known. For example, the FL of a garage could be used as the BM, as the paving has to be flush with the threshold of the garage floor and all other levels can be established from there.

The graduated staff is held vertically on the BM or TBM and a reading taken. With an automatic level, the surveyor will aim the telescope of the level at the staff and adjust the focus until the scale on the staff can be clearly seen. A measurement is then read-off from the cross-hairs of the eyepiece and recorded. With a laser level, the visible laser line will strike the receiver and a measurement can be read-off and recorded by the staff-bearer.



View through automatic level
Measurement reads 1.3 from the scale, with the cross-hairs clear of the 3rd section of the 'E', so the measurement becomes 1.33, and finally the horizontal cross-hair is approximately 4/10 of the way through the white section, so the actual measurement is 1.334m.

Most automatic levels have a magnification of around x10, which makes the staff appear much nearer and larger than it would normally seen. Even at distances of 20m or so, it's fairly simple to read off a measurement to an accuracy of ±2mm.

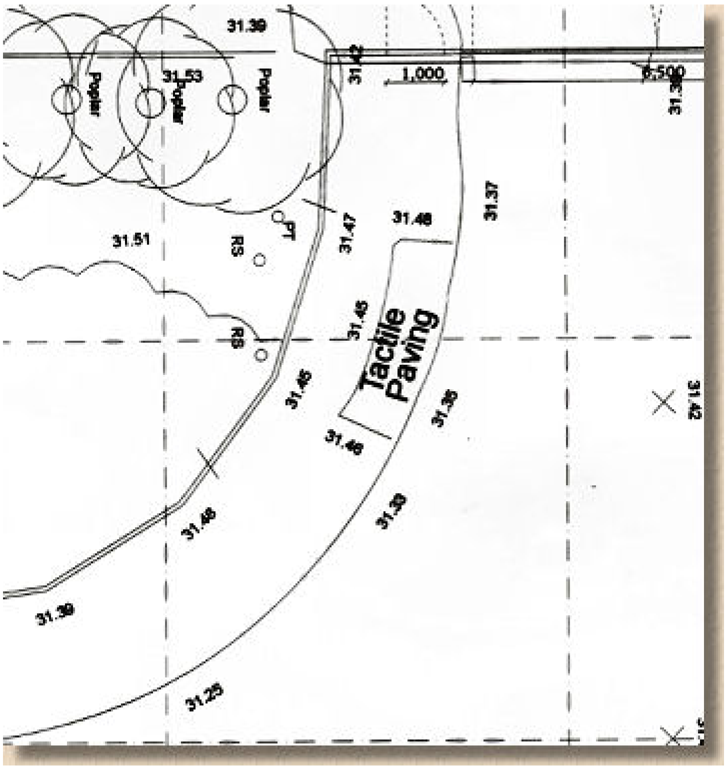
In this example, a reading has been taken and recorded. The next step is to transfer this level to other key points on the project and make adjustments to suit the plans.

Using absolute levels

Absolute Levels means that the spot heights recorded as part of a site survey, or shown on a plan are actually the genuine height Above Ordnance Datum, which normal people refer to as "sea-level". They make a lot of sense if you are building a Nuclear Power Station. They are not quite as important if you are building a driveway where Relative Levels might be more appropriate.

Spot heights explained

The term 'spot height' refers to the 'level' of a particular point on a site, which literally means the height at that spot. The top face of a kerbline at a particular tangent point may have a 'spot height' of 33.564 marked on a plan, and the 'spot height' of the same kerbline, 20m away where the next radius begins is marked as 33.418 so you can subtract one spot height from t'other to find the amount of fall, if any.



Spot heights are typically marked on plans and used to calculate the probable level (height) of intermediate points.

Most large-scale commercial projects will use absolute levels, so that each point anywhere on site is tallied back to one single, universal reference point: the height AOD. Throughout the project, whether it's the roofers, the plasterers or the groundworker, all designs and spot heights are taken from the same base.

There will be some point within or very close to the site that is of a known height AOD and will designated as the Master Benchmark (MBM). These points are usually publicly available known heights - you've probably seen the marks cut into fairly prominent positions on big buildings or large bridges.

For our purposes, we will assume that the level reading shown above has been taken at this MBM, and that the height AOD of this point is 112.575 metres. From this we can calculate that the *line of collimation* ie, the line of sight through an automatic level or projected plane of a laser level must be....

112.575 m (level of BM)
+1.334 m (from staff)
=113.909 m (height of instrument)

Now, if we need to establish a level at a given point (A) that is to be 112.730 m AOD, we can calculate as follows.....

113.909 m (height of instrument)
-112.730 m (required level at A)
=1.179 m (reading to find on staff)

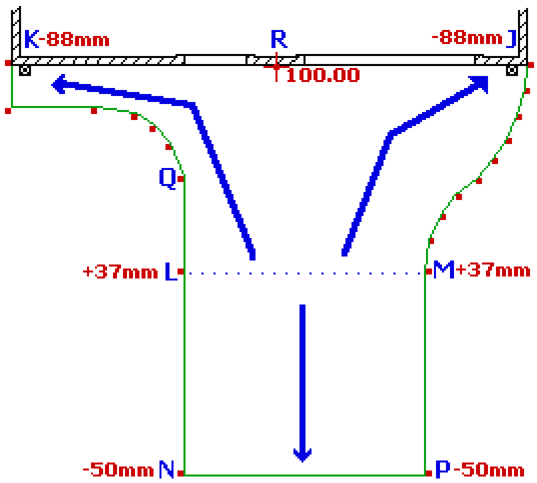
....so at point A, the reading taken on the staff needs to be 1.179m. An operative will hold the staff at point A and raise or lower it as directed by the surveyor until the line of collimation intercepts the staff at 1.179 metres, whereupon the base of the staff can be marked against the pin/peg at point A. Once the pin or peg has been marked or adjusted to the correct level, it should be checked for accuracy again with the levelling equipment.

Using relative levels

On smaller projects, such as home improvements, driveways, patios and so on, the absolute level of any given point is not directly relevant; it's the relationship between various on-site spot heights that is important, and so we can use *relative* levels.

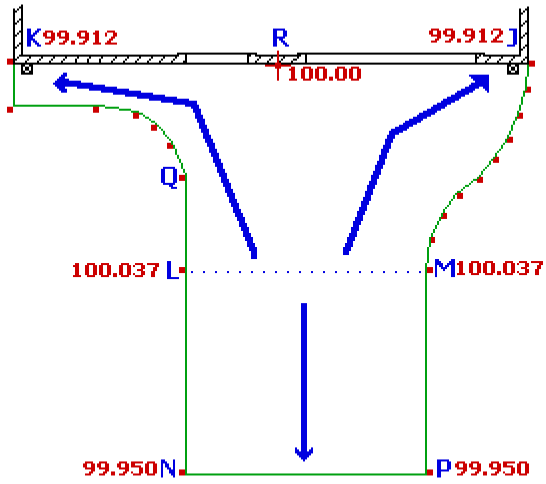
Basically, this means assigning a token level to some fixed point on a project, and then using that point to set out levels for the rest of the site. The token value assigned to a site benchmark ,or 'datum' as it is known, is usually 100.000 metres. This value is chosen so that any levels below the level of the datum are not negative values, which would complicate the arithmetic.

The use of relative levels for setting-out purposes is best illustrated via a worked example. We'll use the driveway project from the previous pages in this Setting Out section of the website. In the Calculating Falls sub-section, the required levels at various key points were established and these are shown on the diagram opposite.



Refer back to Calculating Falls to see how these values were determined.

The 'datum' has been positioned at point R, declared to be 100.000 metres and all other levels will be determined from that.



These plus or minus values need to be converted to values that are relative to our datum at R. They are usually referred to as 'Reduced Levels' or RL.

Point K is given as -88mm, relative to Point R, therefore....

100.000 - 0.088 = 99.912

.....we can repeat this arithmetic for the other key points, and these are shown on the drawing opposite.

As explained above, we now need to establish a value for 'height of collimation', and so a reading must be taken from the staff held vertically at Point R. For ease of argument, we'll assume that the reading taken from the datum point, R is again, 1.334 metres.

This tells us that the height of instrument is, therefore, 101.334 metres.

The points J and K are to be set at 99.912 metres, so, a simple bit of maths gives us.....

101.334 - height of collimation
- 99.912 - level for points J&K
= 1.422 - target reading for staff

....and this process is simply repeated for the other points, working out what the staff reading needs to be at each point to establish a correct level........

Points L&M

101.334 - h.o.c
-100.037 - level at L&M
= 1.297 - target

Points N&P

101.334 - h.o.c
- 99.950 - level at N&P
= 1.384 - target

....Now that our targets have been calculated, the procedure for level transfer outlined above can be used to establish levels at points J,K,L,M,N and P in one operation.

In most setting out jobs, there is more than one way of skinning a cat, and we could have transferred the datum level (100.000) to all the relevant points and then measured up or down from the datum mark accordingly to find the required level at each point.

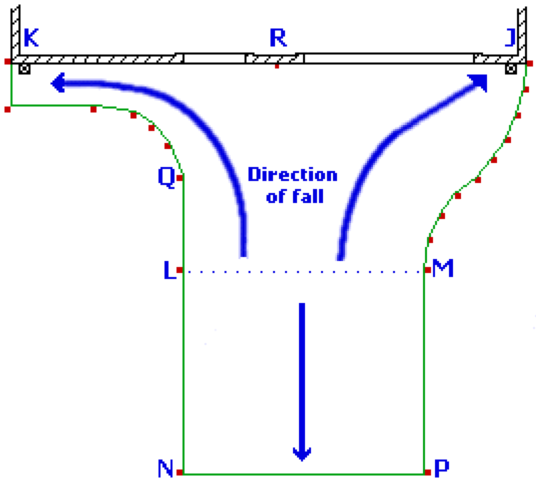
Further, I've tried to avoid overly technical jargon and have only skimmed the surface of the world of surveying and setting out, so please don't regard the above as a definitive guide to the use of automatic and laser levels. It's a brief introduction and nothing more.

Working Lines and Levels

Setting line levels

The pins have been positioned and the string line established so now we need to set the string line to the correct level at each pin. With the half-hitch knots, by pulling the string line on each side of the pin towards the pin itself, the tension on the half-hitch is reduced allowing it to be moved up or down the pin as required.

The drawing opposite shows that the part of the driveway nearest the house is going to be drained to the gullies at J and K, while the lower part of the drive is going to be drained towards the public footpath. This leads to the creation of an imaginary 'change of fall' line between L and M, which explains the reason for the intermediate pin L on the straight line N-Q.



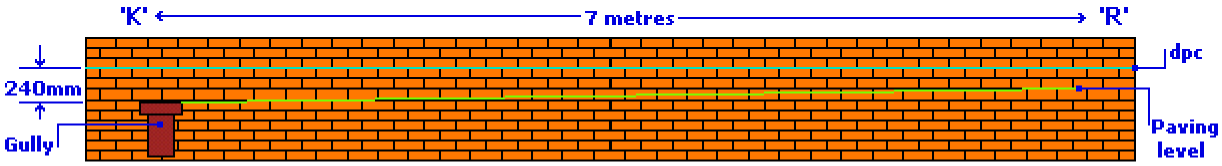
It can also be seen that the driveway needs to slope in two directions along the front of the house, with a high point at R and falling towards the gullies at J and K, respectively. We know that, as R is a point against the brickwork of the property, it cannot be any higher than 150mm below damp proof course (dpc), and so we can set that point immediately.

Calculating Falls

We also know that R is equidistant between J and K, and so is approximately 7 metres from each gully. We need a minimum gradient of 1:80 to ensure surface water will drain on a block pavement such as this. Other surfaces, especially hand laid tarmac, need a steeper gradient than this, say 1:60, to ensure adequate drainage.

So, 7 metres at a gradient of 1:80 = 7 × (1÷80) = 7 × 0.0125 = 0.0875m = approx 88mm.

We now know that the level at the gullies must be 88mm lower than at point R, which has been established as 150mm below dpc, so J and K must be (150 + 88) = 238 mm below dpc (assuming dpc is level). Measuring down from the dpc, we can mark this level onto the brickwork, and adjust the gully levels to suit.



Cross-sectional view through K and R showing fall to gully

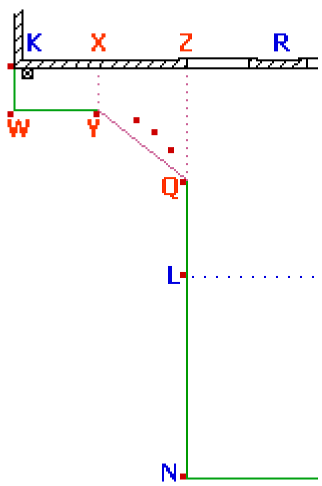
Now we have R, J and K established, the next critical levels to set are the high points on the driveway, on the break line L-M. We can measure that from the centre point of the break line L-M to the furthest gully, K, is approximately 10 metres. Using the standard 1:80 fall, we can calculate that the midpoint on line L-M needs to be......

10 × (1÷80) = 10 × 0.0125 = 0.125m = approx 125mm higher than the gully at K.

We know that the gully is 88mm below R, so Points L and M need to be 125 - 88 = 37mm higher than point R. We also know that the threshold level, N-P is 50mm lower than Point R, so there is (37+50) = 87mm of fall from points L and M to points N and P, a distance of only 6 metres, which is a fall of (87 ÷ 6000) = 1:67, well within our 1:80 minimum.

Level Transfer

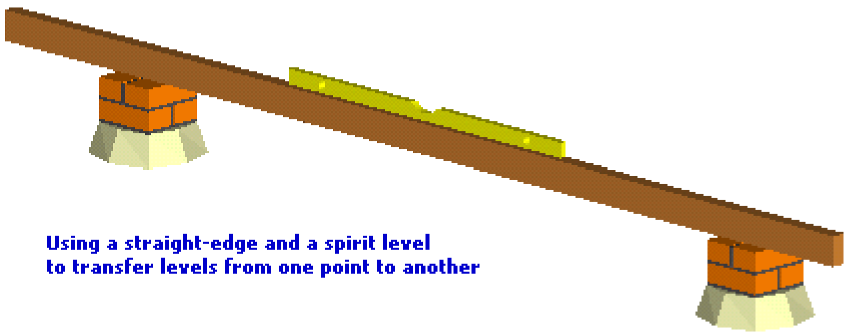
This sub-section describes simple techniques for level transfer using everyday tools. For a more 'scientific' approach, see below on boning rods and automatic levels.



Levels for key points on layout

We can use a straight edged timber and a good spirit level to transfer the level from Point R to points L and M, and then add 37mm. Small boat levels, 200-300mm long are not usually accurate enough for this sort of work, and so we recommend a spirit level at least 1200mm in length to be accurate when transferring the level by means of a straight edged timber, 3 to 4 metres in length. However, it is obvious that even a 4m straight edge will not span the distance from R to L or M, and so we set up a temporary intermediate level.

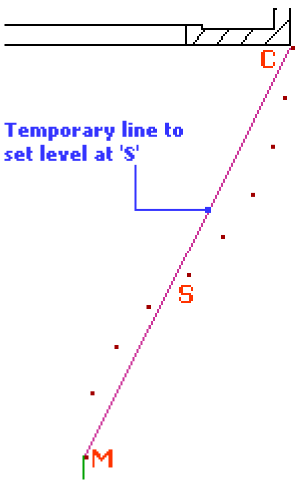
A brick is set on a sand bed at Point R so that its surface is at exactly the correct paving level, ie, 150mm below dpc. Another brick is then set up between R and L, also on a sand bed. The straight-edge is then placed to bridge the two bricks, and checked with the spirit level. The intermediate brick is tapped down until the spirit level tells us that it is exactly level with the brick at Point R.



This method of level transfer is only suitable for use on small projects, and a level should never be transferred in more than 2 stages, to keep errors to an acceptable minimum.

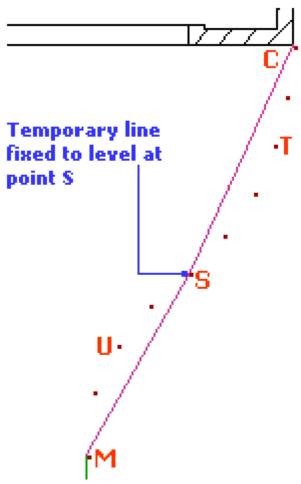
By using an intermediate level transfer, we've now established the paving level at points L and M, and, from earlier, at points J, K and R. We have the level of the existing footpath to tie in to at points N and P, leaving only the levels to be set on the intermediate pins around the curves.

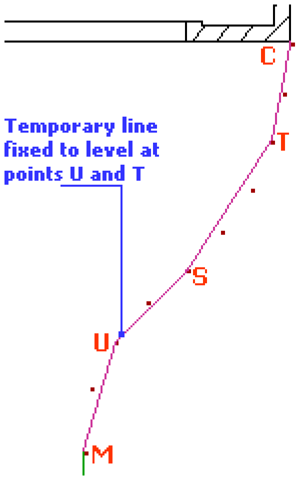
Setting Levels to Curves



Dealing first with the S-curve on the right hand side of the driveway, by stretching a line between known point C and known point M, it can be seen that this temporary line passes very close to one of the marker pins at 'S'. The spirit level can then be used to transfer the level from the temporary line to the nearest pin.

The temporary line is then looped around pin S with a half hitch as shown above, and the spirit level used to transfer a level from the temporary string line to the intermediate pins at T and U.





Once the string line is half-hitched around the pins at T and U, the process is repeated until the line level is set on every pin between C and M. By lying flat on the ground, with your eye level with the string line, and looking along it, there should be no obvious high or low points as the line snakes its way around the pins from C to M. Minor adjustments to the level at each pin may be required to ensure the level is 'sweet' along the line.

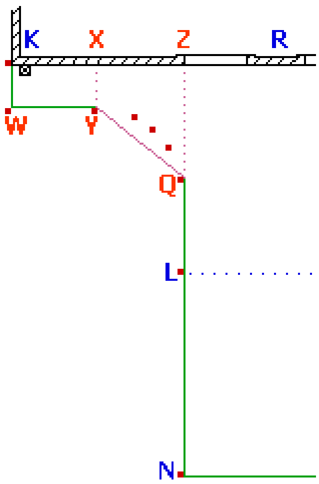
When the levels are established on each pin, by repeated transfer as explained, the line can be set up permanently as a guide to paving level. In this scenario, the soldier course edges to the driveway will be laid on a concrete bed and tapped down until the top of the block is level with the taut string line.

Setting Intermediate Levels

The curve on the left hand side of the driveway, and the short access path along the front of the house will have levels set on them next, completing the last stage of the setting out work.

The curve itself can be set out using the principles described above for setting levels on the S-curve, but the paving level at Points Q, Y and W should be established first, reducing the amount of level transfer from string line required, and therefore maximising overall accuracy.

Firstly, Point W can be established by levelling across from the top of the gully at point K and allowing this 1.2 metre wide path to slope towards the gully by approximately 20mm, which is well within the 1:80 tolerance specified. So, point W is 20mm higher than Point K.



Point Y is similarly established, by levelling across from the line established between K and R at point X. However, at this point, we do not want the path to fall towards the house, as we did for the previous point, as there is no gully at point X. Therefore, we will set Point Y at 10mm below point X.

Point Q is established by extrapolating the line N-L until it intercepts the line K-R at point Z. The taut string line will just touch the pin at Q, which can then be marked for paving level.

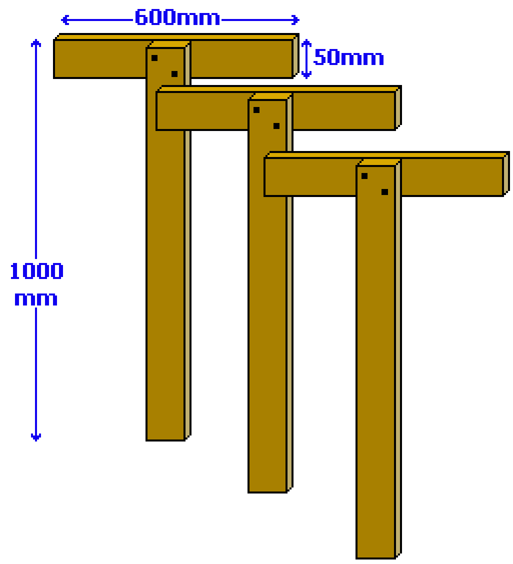
Finally, the paving level can be transferred, as shown above for the S-curve, from a temporary string line stretched between known point Q and known point Y.

The job is now set out for line and level. After a thorough check that the levels seem right and the alignment is true, the paving work can begin.

Boning Rods and Sight-rails

The use of boning rods to establish levels is one of the very earliest construction technologies that is still in everyday use, thousands of years after they were used extensively on Sumerian and Ancient Egyptian building sites. The term 'boning rod' comes from and Old English term for a slope or gradient, a bone. It's one of those notions that's so simple, that it's hard to improve upon, and it's only the advent of cheap laser levels over the past few years that has seen this technique become less common.

The basic premise is that by establishing two fixed levels, it is a simple matter to use the line of sight to set any number of intermediate levels. The 'kit' consists of 3 T-shaped staffs that are typically identical, although when 'fixed' sight rails are used, the 'traveller' may be constructed to a specified length. Most paving and groundworks contractors will have a set of boning rods that they can use on successive jobs, but where a large number of levels are to be established, fixed sight rails may be preferred.

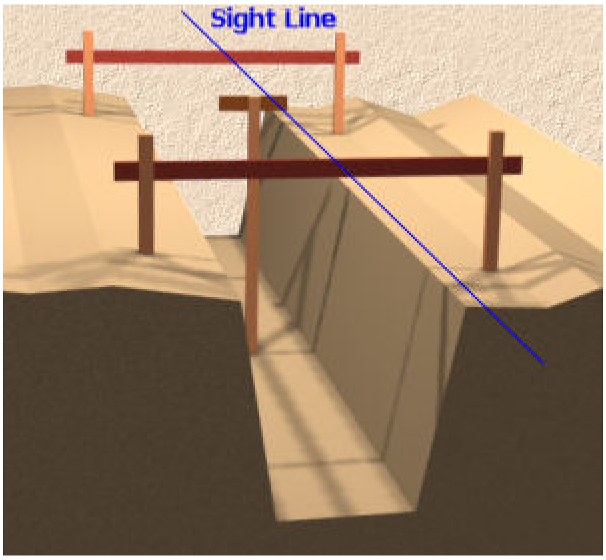


Typical Boning rods

When using a set of 3 boning rods, one rod is set up at a specified height above a known level. Normally, some form of stable, temporary platform will be constructed from bricks or broken flagstones so that the top of the platform is set to the correct level. The boning rod is then simply stood atop the platform and held in position by an operative or a brace. Another rod is similarly set up at the next level point. It is essential that the cross-pieces of these rods are perfectly horizontal, and they should be checked with a spirit level before use.

The third rod is known as the Traveller, and this can be held in position at any point between the two established rods. A steel pin or timber peg will be driven into the ground at the point where an intermediate level is required and the Traveller held against or on top of the pin. An operative at one of the established levels then sights through over the Traveller to the backsight rod, and instructs the operative holding the Traveller to raise or lower it accordingly until it 'bones-in' between the foresight and backsight. Once the Traveller is at the correct level, the operative can mark the pin at the base of the staff or adjust the height of a peg to the required level.

This point has now been set to a plane level between the two established levels. Any number of intermediate levels can be set in this manner, and the spread of the cross-pieces allows for some deviation from true line to be accommodated, as when setting out curves or arcs. Once the intermediate levels have been established, adjustments can be made as required; for example, we may have two points that are level with each other and wish to establish an intermediate level that is 100mm higher to generate fall for a pavement. The intermediate level can be established as outlined above and then 100mm added to the height.



Boning-in is especially useful for excavations and trenches, as proper sight-rails can be set up in advance and a traveller constructed to guide excavation depth to whatever reduced level is required. For drainage projects, it's usual to have the sight-rails set up outside the excavation limits and up to 50m apart. A mechanical excavator can work its way along the line of the trench and rely on the banksman to use the traveller to test whether excavation depth is acceptable, too deep or not deep enough every few metres of linear excavation.

Boning rods in use on site:

Opposite: a backsight rod is set up by attaching it to a brace that will hold it erect on the surface of the existing road at the lower end of the excavation.

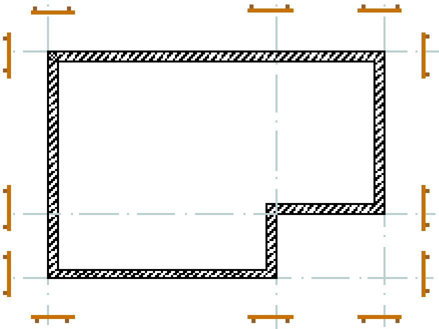
Below Left: A foresight is positioned at the opposite end of the excavation. As you can see, only the very best quality timber is used to construct these high-tech surveying aids!

Below right: One operative holds the Traveller Rod within the excavation, while a second operative peers over the Foresight Rod and sights through to the Backsight Rod. As should be apparent, when the Foresight and Backsight rods are visually aligned, the Traveller Rod will be "high" indicating that further excavation is required at that particular spot.

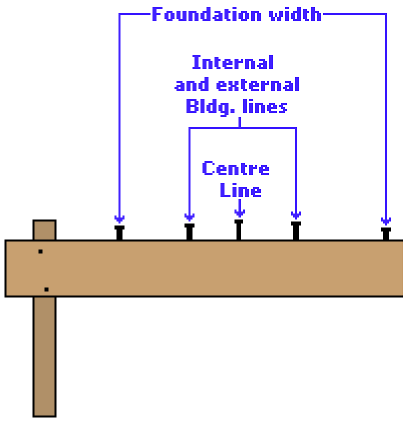

Backsight
Traveller
Foresight

Profile Boards

Sight-rails are often used when setting out house foundations, when they are sometimes known as 'Profile Boards'. These are established outside the limit of excavation, and always in pairs. They can then be used not only as sight-rails with a traveller to check on excavation depth, but also to set levels for top of concrete foundation, internal floor level, finished ground level, etc.



Sight-rails set up to guide excavation of strip footings for a typical house



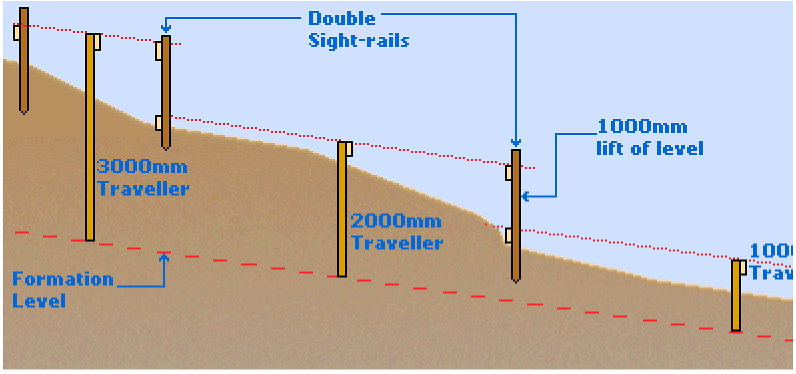
These Profile Boards are also used by the groundworker to establish foundation width, and by the Bricklayers when they come to start laying the masonry. A number of nails are knocked into the top of the Profile Board directly upon the relevant line to which it relates. The groundworker will use the centre line and foundation limits to guide the line of excavation, and use a Traveller with the Profile Boards to check the depth of the excavation. The Brickies will rely on the Building Line nails to guide their setting out, especially the positioning of corners.

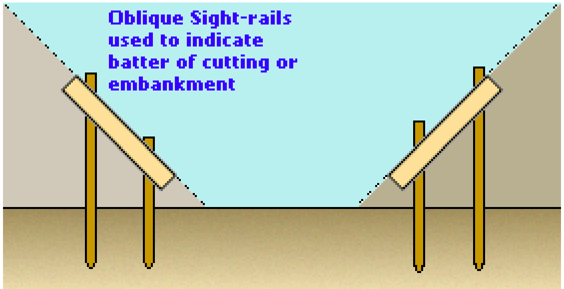
Other uses of Sight-rails, Profile Boards and Travellers

These techniques are used in many areas of groundworks, such as gradient formation, trench cutting, area cut and re-grade and cutting/embankment batter.

This diagram below illustrates the use of double sight-rails to guide the excavation of a steady gradient trench through undulating ground.

The traveller length has to be adjusted between sets of sight-rails. In this simple example, each 'lift' of the sight-rails has been set at 1000mm, and so the traveller length must increase by the same amount to maintain accuracy.





Oblique sight-rails are used to guide the amount of batter used when creating an embankment or excavating a cutting. These sight-rails are usually placed outside the working area, but in a position such that they can give a quick confirmation that the work is as required.