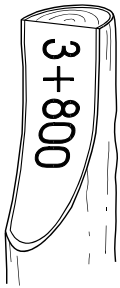


8.2 Instruments and Surveying Aids

There are a number of appropriate methods for setting out the road alignment. The surveying equipment required is based on the setting out methods chosen. When choosing a specific method of surveying, it is important to bear in mind the required level of accuracy for the works. Obviously, the requirements of a rural road may not be the same as for major highways or city streets. Bearing this in mind, the following section describes some low-cost but still accurate enough methods of setting out rural road alignments.

8.2.1 Types of Survey Equipment and Use

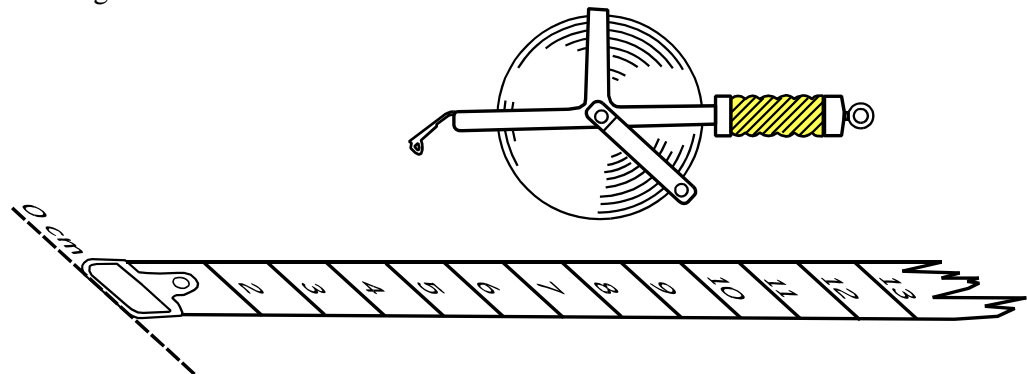


Reference pegs are used to mark the alignment and road levels. They are invariably of wood, tree branches or stakes cut to length, ideally 40 cm long and 5 cm diameter or 5 cm x 5 cm square. It is advisable to paint them white or yellow for visibility and paint the chainage on a prepared face. To avoid loss or damage, the pegs should be offset from the road width, hammered deep into the ground to avoid pilferage and placed in a prominent location.

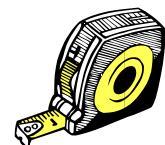
Survey pegs are usually set on the centre line, but unless there are no earthworks to be undertaken, they should be off-set from the road width. Multipurpose pegs may be needed to stake out cross-section, tasks, levels, etc. They are normally sharpened sticks 30 cm long used in conjunction with a string line to define horizontal or vertical alignment.



Tape measures are made of steel or linen, the most useful length is 20 or 30 meters. Steel is expensive, liable to damage and illegibility after a period of use. It is recommended that the linen tape are used although they are not quite as accurate as steel. Tapes are vital for length and width setting out as well as setting tasks or defining contract limits.

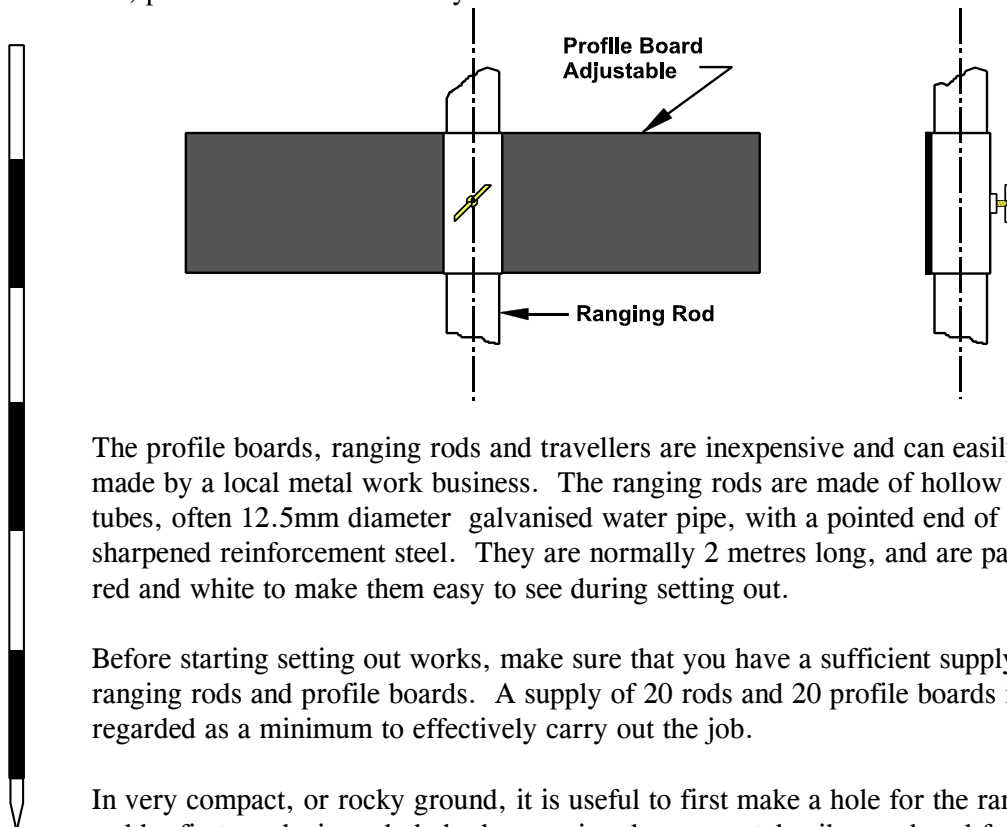


Smaller tapes, 2m, 3m or 5m in length, are useful for small construction elements, such as profiles of ditches, raising cambers, etc.



Profile Boards and Ranging Rods are useful for setting out levels. Also, the ranging rods are used for setting out straight lines and curves.

A long lasting profile board is made from thin steel plate which is welded to a short length of metal tubing that can slide up and down and be clamped to a metal ranging rod. A useful size for the metal profile boards has been found to be 40 cm by 10 cm, painted red to make it easy to see.



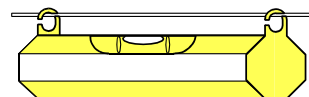
The profile boards, ranging rods and travellers are inexpensive and can easily be made by a local metal work business. The ranging rods are made of hollow metal tubes, often 12.5mm diameter galvanised water pipe, with a pointed end of sharpened reinforcement steel. They are normally 2 metres long, and are painted red and white to make them easy to see during setting out.

Before starting setting out works, make sure that you have a sufficient supply of ranging rods and profile boards. A supply of 20 rods and 20 profile boards is regarded as a minimum to effectively carry out the job.

In very compact, or rocky ground, it is useful to first make a hole for the ranging rod by first producing a hole by hammering down a metal spike produced from high tensile reinforcement steel. Crow bars can also be used for this purpose.

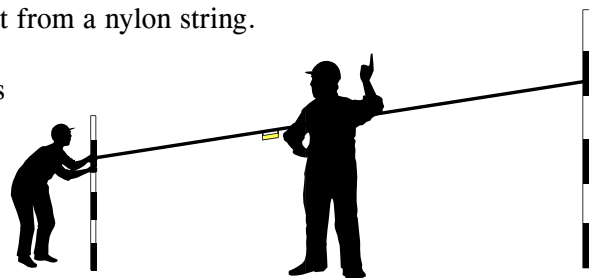
A very useful additional tool is a *sliding hammer* with a weighted head that fits over the ranging rod and can be used to drive the ranging rod into the ground.

Line Level






The level of each of the profile boards can be controlled by using a *line level*. The line level is a short spirit level (about 100 mm long) with a hook at each end to hang it from a nylon string.

This instrument needs two persons to operate - one at the end of the line, and the second to watch the spirit level. The line operator moves the string up or down until the bubble is centred in the middle between the



spirit level marks. The string line will then indicate the horizontal line. The line level can be used to:

-  transfer the exact level of one profile board to another profile, thereby ensuring that both are at the same level,
-  measure up or down from a known horizontal level, and set a new level, and
-  find the slope between two fixed profile boards, and determine which one is higher.

The line level has a range of up to about 50 metres. It is easy to carry around and with care can be used for setting out levels and slopes not less than 1 in 300.

Points to remember when using a line level:

- T The string used should be a thin nylon fishing line, enabling the line level to easily slide along the string.
- T The line level must be placed half-way between the two ranging rods. Use a measuring tape to find the exact middle point.
- T Keep the string tight - do not let it sag.
- T The line level is an delicate instrument, look after it - do not throw it around and treat it roughly.
- T Check the accuracy of the line level regularly in the field.



Checking the Line Level

Take two ranging rods across the road and transfer a level from one rod to the other. Mark the level on the second rod.



Then keeping the string in the same position on the first rod, take the line level and turn it around on the string. Adjust the string on the second rod until the bubble is in the middle again and mark the new level.



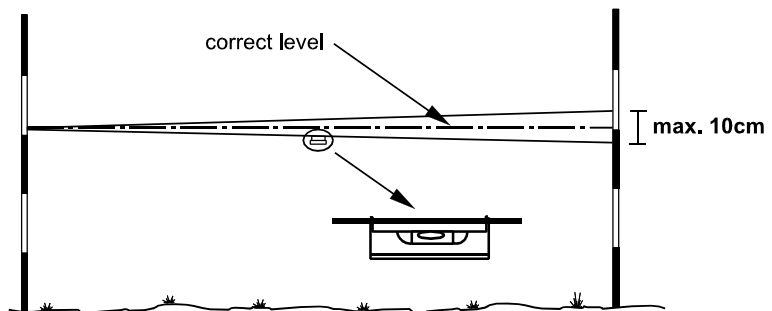
Check to see if the two marks are at the same place. If not, measure the difference between the two marks.



If the difference between the two marks is less than 10 cm, you can get the right level by taking the point half way between the two marks.

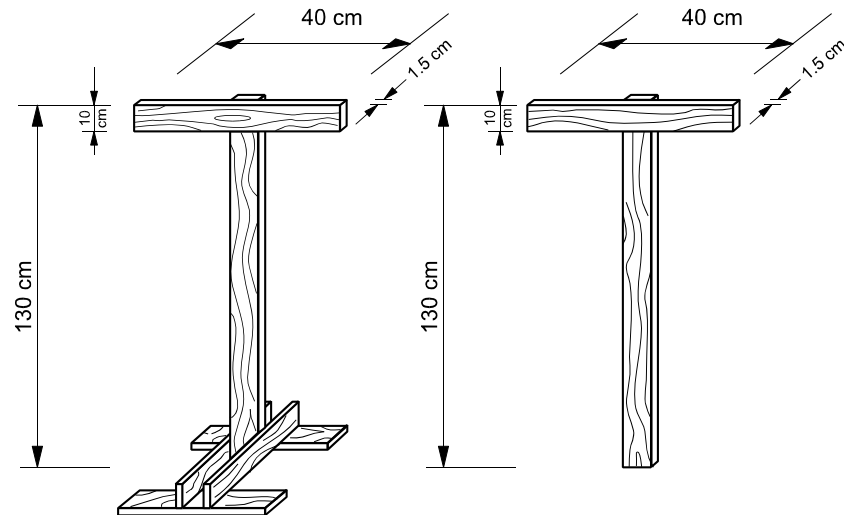


If the difference is greater than 10 cm, you should replace the line level for a new and more accurate one.

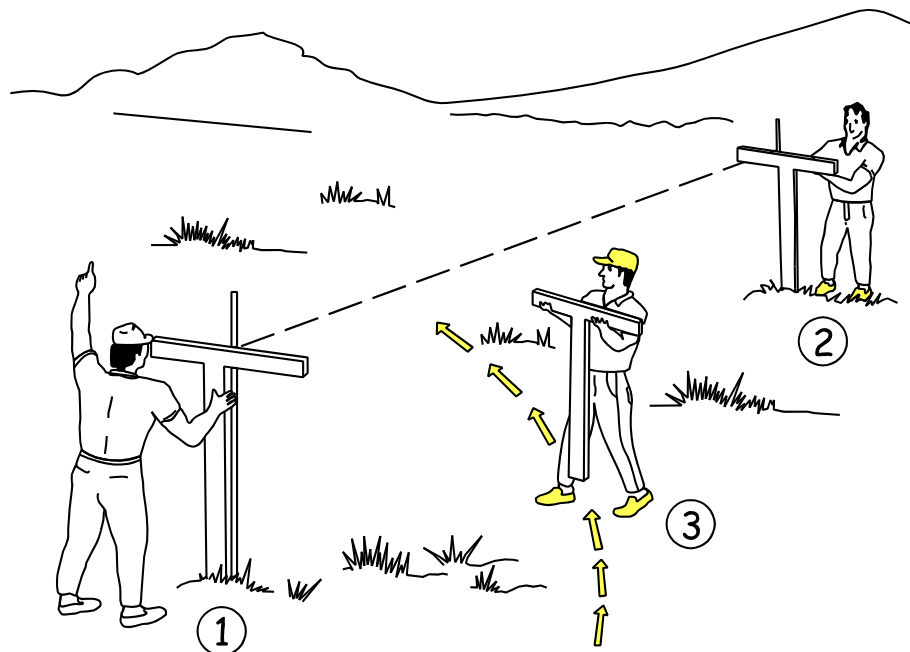


It is always a good idea to turn the line level around every time you use it and take the middle of the two marks as the horizontal level.

Boning rods are generally manufactured on site from wooden laths to a " T " profile and of uniform height. A simple stand can also be manufactured.



Boning rods are used in sets of 3 and the crosspiece is frequently painted, ideally each with a different colour. They are used to establish additional levels between fixed levels (interpolation) or beyond (extrapolation). They are particularly useful to check gradients of ditches and culverts. In the figure below, it can be seen that the ground level at point 3 is too low and the boning rod is positioned too far to the right. By raising this boning rod and aligning it with rods 1 and 2, the bottom of rod 3 indicates the required level and its location is on a straight line.

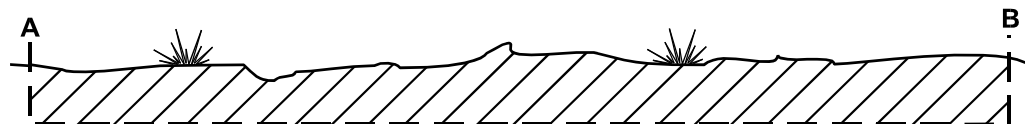


The same exercise can be carried out using profile boards, with the advantage that it would only require two persons to perform the task.

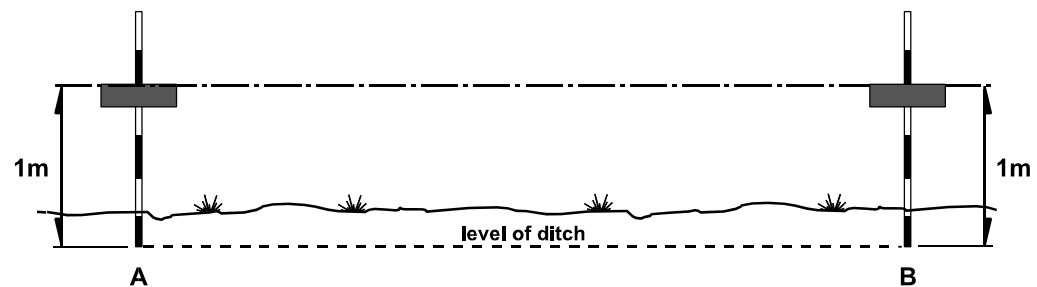
The Profile Board Method

A commonly used setting out procedure is based on the use of a series of profile boards and a string line level giving control of levels during construction. The basic principle when using profile boards is that when they are set out we are placing a series of level boards that show the level 1 metre above the completed construction levels.

Imagine that a ditch is to be excavated from A to B at the level shown in by the dotted line:

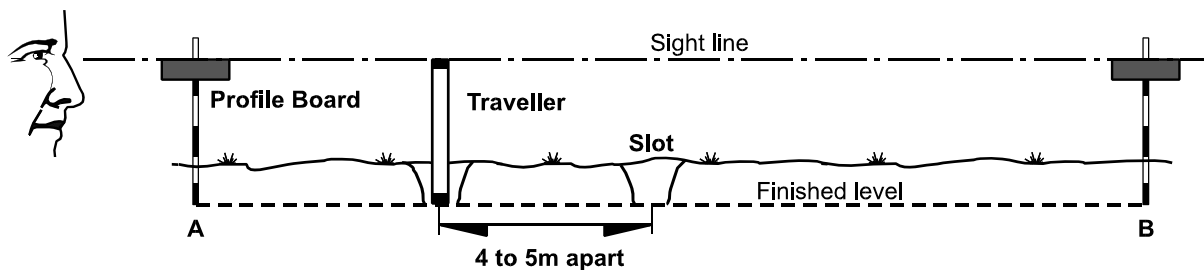


To ensure that the correct level is obtained in the ditch, profile boards are placed at positions A and B, 1 metre above the level of the planned ditch:



Traveller

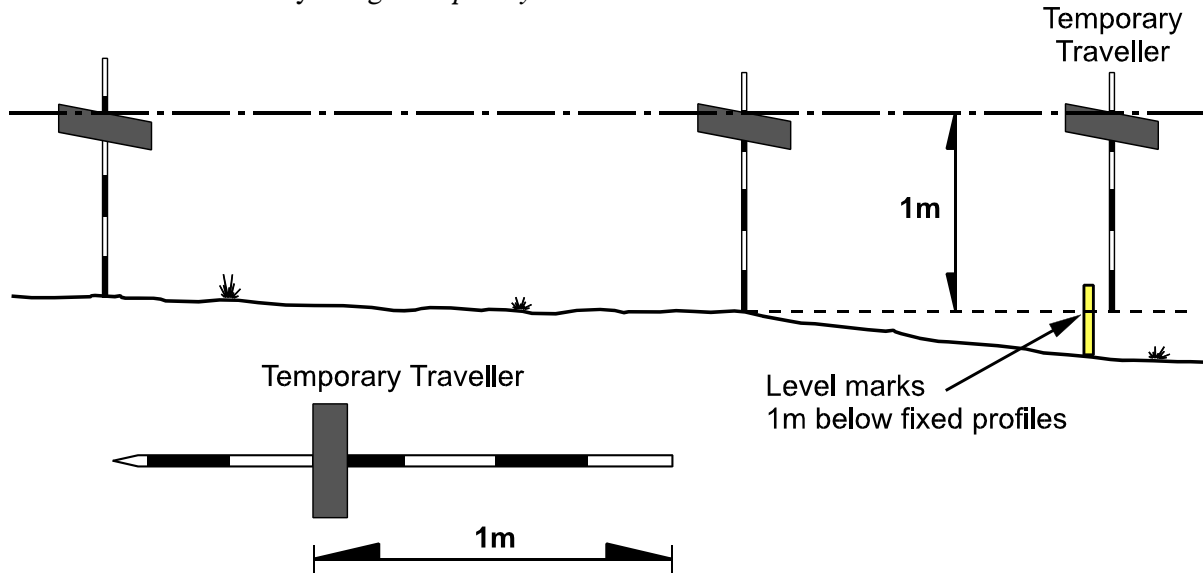
A travelling profile is used to obtain levels between two profile boards. A boning rod or a profile can be used as a traveller. Along the line from A to B, slots are excavated to the level of the ditch. By placing the traveller in a slot and sight from the profile board in position A to the profile board in position B, we can see if the traveller lines up with the two fixed profile boards. If the traveller is too low, the slot has been dug too deep. If the traveller sticks up above the sight line, the slot needs to be dug deeper.



To provide good guidance, slots are dug at regular intervals, say at every 4 to 5 metres along the sight line. When sufficient slots have been dug, the workers can start excavating the ditch by joining up the slots. The traveller can then be used to check that the finished work is to the correct level and that there are no high or low spots.

Temporary travellers

It is also possible to take measurements below the line sighted between two profile boards by using a *temporary traveller*.



The temporary traveller is easily made on site by measuring the length needed from the blunt end of a ranging rod to the further edge of the profile, which is then clamped in position. The temporary traveller is then ready for use.

When used with fixed set out profiles, the traveller will give an indication of the finished construction levels anywhere along the sight line of the set out profiles.

This is very useful for the site supervisor when setting out. The most frequent use the supervisor will make of temporary travellers, is to mark earthwork levels on the edge of road pegs. But there are other uses for the traveller:

- T to guide and check excavation below earthwork levels (eg. for excavation for drift base construction),
- T to find out whether large boulders are above or below road levels before the road levels are finally decided upon,
- T to estimate the amount of fill needed if the road is "lifted", or when the road crosses low areas - this will help estimate the work involved and help decide on the optimal road levels,
- T to locate the end of drains and approaches, and
- T to provide a quick check on work, levels, string lines etc.

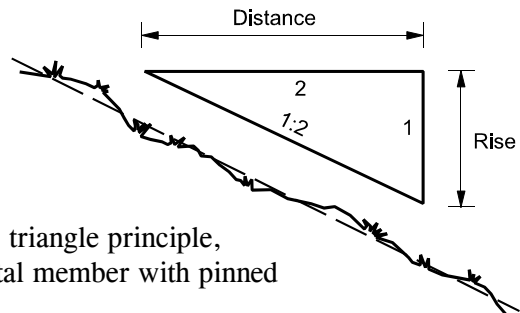
However, for guiding drainage work the labourers and gang leaders should use the specially built travellers or a boning rod. This is because the profile on a temporary traveller can become loose and the supervisor may not be present to check and re-set the traveller length.

Triangles

Triangle sets can be manufactured by the site carpenter from laths and used for various purposes:

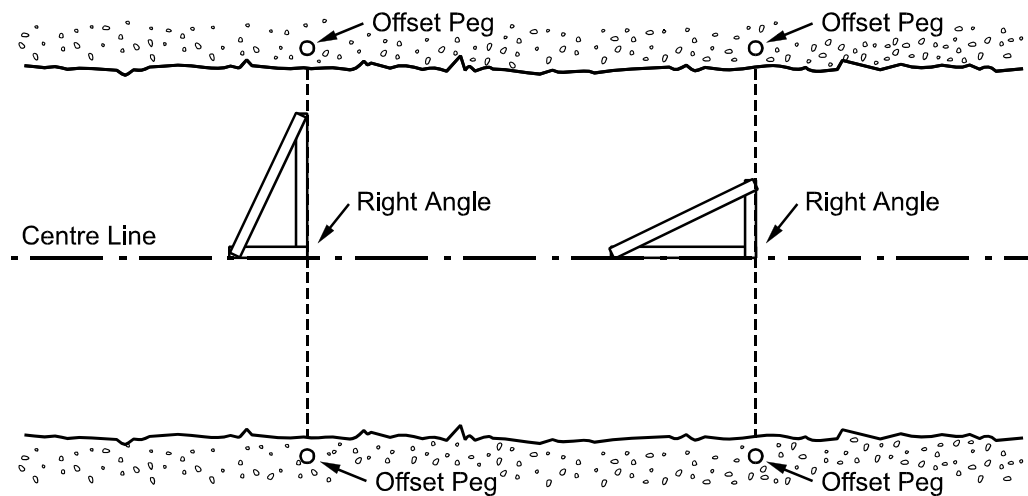
- to set out a right angle to the centre line (which has to be done when cross-sections are set out);
- to control or estimate the steepness of gradients - in this case a spirit level or plumb line is also required.

The steepness of gradients is described as a ratio. For example, a gradient of 2 : 1 means two metres horizontal one metre vertical.

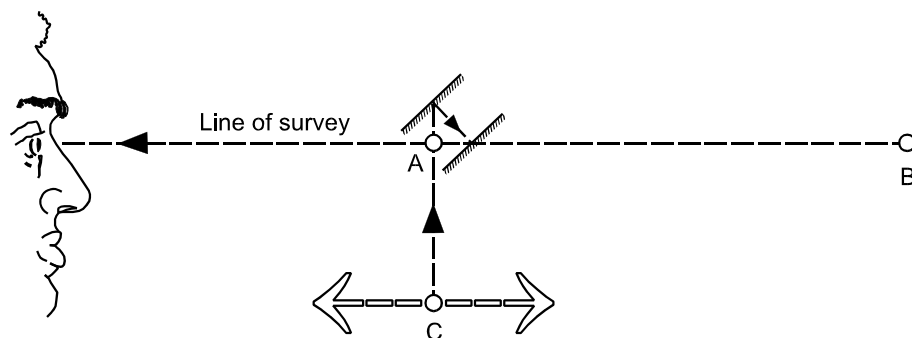


Existing gradients are measured using the triangle principle, incorporating a spirit level as the horizontal member with pinned joints rather than fixed.

The triangle can also be useful in establishing a right angle to the road centre line as illustrated in the figure below.



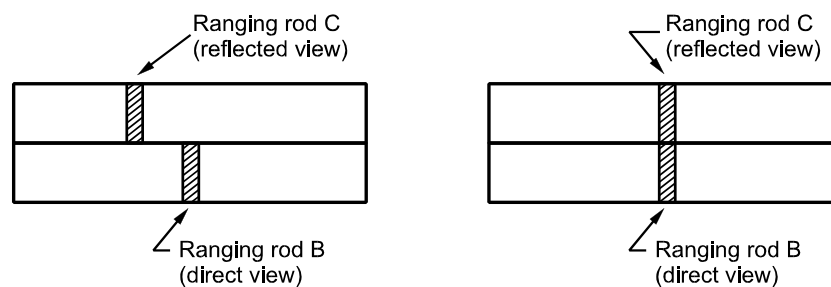
Optical Square is a small instrument using either mirrors or a prism to establish a right angle as illustrated in the figure below.



The observer can see both point B, through a narrow opening left in the optical, square and point C in the mirror or prism.

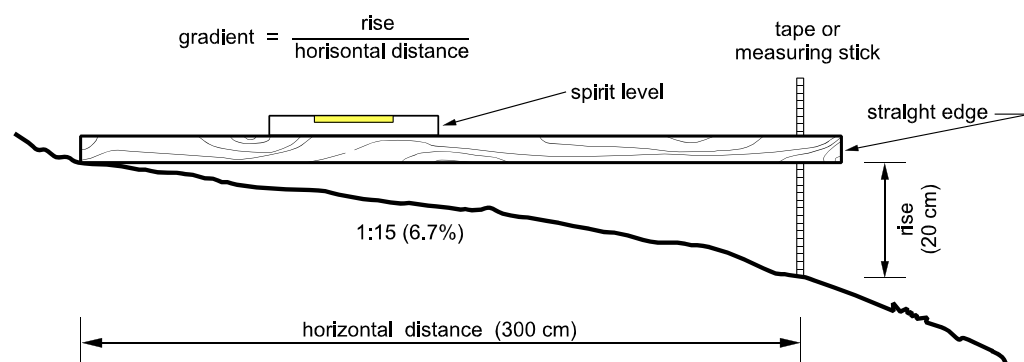
When two ranging rods are placed at points B and C, the observer will see ranging rod B direct and ranging rod C reflected as illustrated in the figure below.

When points A and B on the survey line are known and point C has to be found, as shown in the figure above, the person holding ranging rod C should move forwards or backwards until the observer see the reflection of rod C in one line with his direct view of rod B. At this point angle CAB, is now at a right angle.



Straight Edge is a simple beam, usually wooden, which in conjunction with a spirit level and tape measure, can be used to establish a gradient/or road camber.

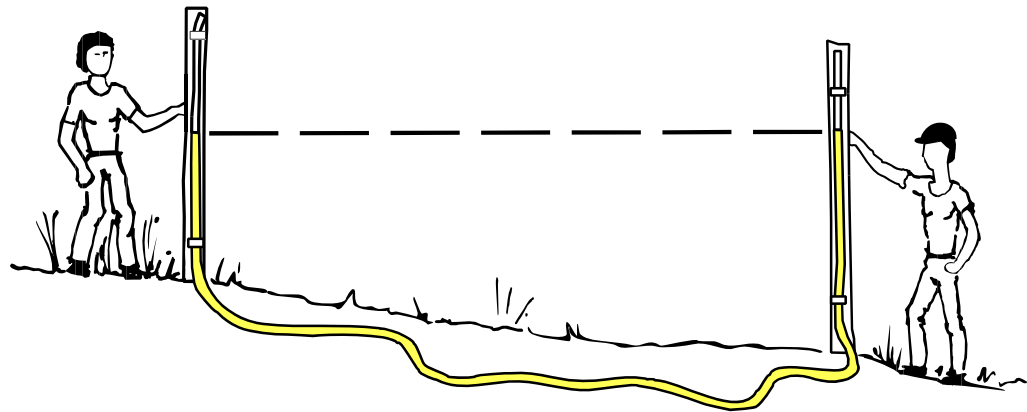
The straight edge is usually 3 metres long and set horizontally with the aid of a spirit level. This method should be used for the measurement of gradients which continue only for short distances, e.g. culvert beds, drain slopes and road camber. The figure below shows how a gradient of 1:15 is measured.



Tube Water Level

A very accurate and simple instrument for measuring the level differences of two points is the "tube water level".

This level, illustrated in the figure below, consists of a length of clear plastic pipe clipped at each end to a wooden levelling staff. The two levelling staffs should be of the same length, about 1.5 m long. A graduated tape is attached to each stave, with the zero level with the top end of the stave. The tube is filled with water until the level is about 1 m high from the ground. The ends of the tube are fitted with rubber stoppers to prevent loss of water. The total length of tube, which defines the range of the instrument, is variable, but is usually limited to about 15 m by the difficulty of moving the level around.



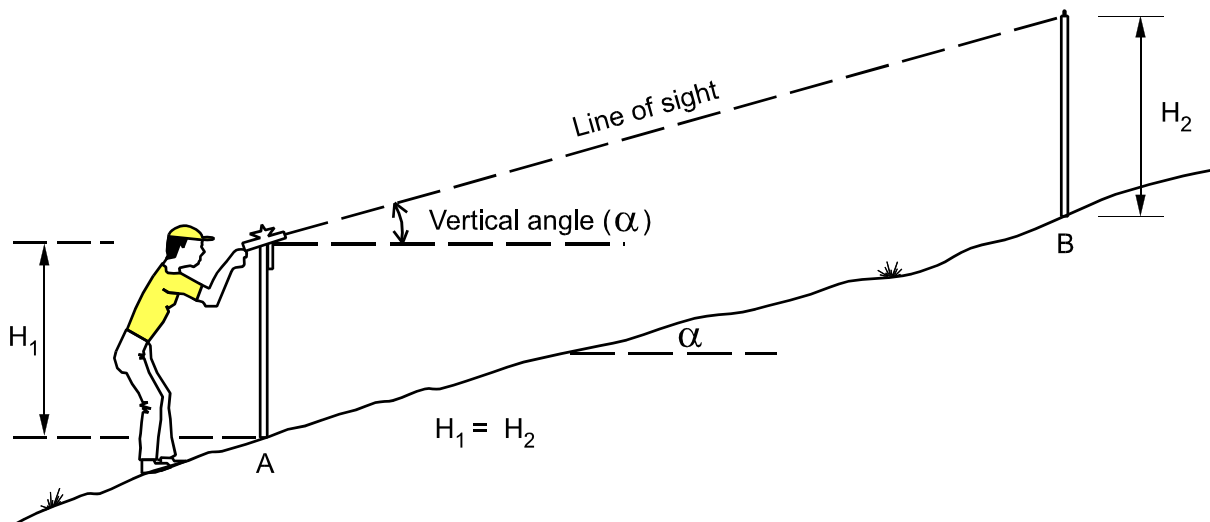
The two standpipes are brought together at the starting point, the stoppers removed and the readings taken level with the bottom of each meniscus. The readings should be the same (e.g. reading A = 50 cm, reading B = 50 cm). The surveyor takes his/her standpipe to the point being measured and takes another reading. The difference between the two readings is the difference in level (e.g. now reading A = 30 cm and reading B = 70 cm, the difference in level is now $70 - 30 = 40$ cm).

Range is limited only by the convenience of being able to carry the tube. The two points whose difference in level is being measured do not need to be in sight of one another. The level gives accurate results and with care can be used for setting level lines or slopes not less than 1 in 1,000.

Abney Level can be used for the measurement of vertical angles for setting out levels.

Vertical angles, are measured as follows:

The sight is taken on to a point which should be at the same height above the ground as the eye of the observer. The line of sight will then be parallel to the ground surface between A and B (see figure below).



Holding the abney level in this position (the cross hair intersects the target), the air-bubble in the tube of the abney level should be positioned in the middle against the cross hair by turning the milled head. The angle of the line of sight with the horizontal can then be read on the arc.

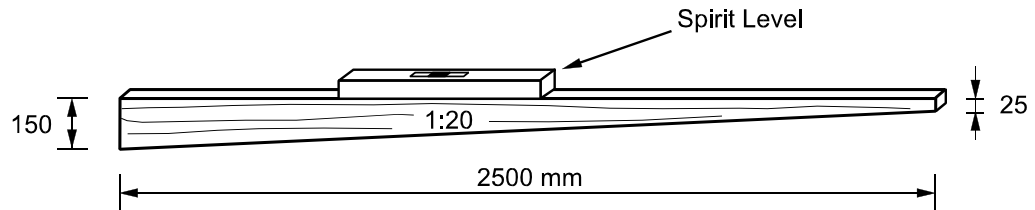
The abney level can also be used to set out gradients. The arc should be set at the required angle or gradient (e.g. $5^\circ 40'$ or 1:10) and a line of sight established to a profile board which is moved up or down until the top of the profile board is at the correct height.

Finally, the abney level can be used to measure distances and to transfer heights. The degree of accuracy that can be achieved, however, is not very high. Where greater accuracy is required it is recommended to use tape measures for distances and levelling instruments for heights.

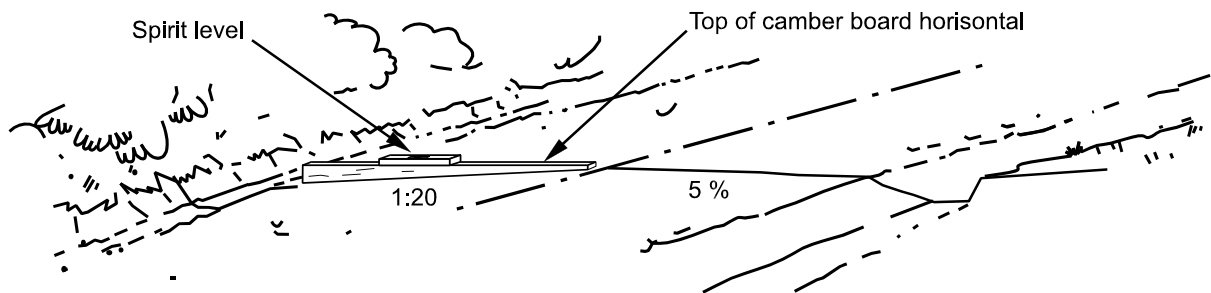
The **dumpy level** is used to measure height differences used in combination with a levelling staff. Levels can be transferred from a bench mark and new levels can be established very accurately over distances up to 100 meters. There are several types of dumpy levels on the market, each with its own system. It is recommended that engineers or surveyors should practice using the instrument by checking its accuracy before taking it into the field.

A **camber board** can be used to establish the camber of the road. Its length is usually the distance from the centre line to the shoulder of the road. In cases where the shoulders have the same gradient as the running surface, the length of the camber board can also include the shoulder.

The figure below shows a 2.50 meter long camber board showing a gradient of 6 percent (1:20). The length and gradient should be modified to suit the required profile.



The camber board is used in combination with a spirit level as shown below:



Ditch templates are generally a trapezoid constructed of timber laths or plywood to check the profile of ditches, mitre drains, back slopes, etc.

