26.2 Vertical Alignment

In its simplest form verticality is measured by using a *plumbline* (a string line with a weight attached). For short structures, plumbing of modest accuracy can be achieved using a good quality 1m spirit level, but as the height and/or need for precision increase other methods must be used.

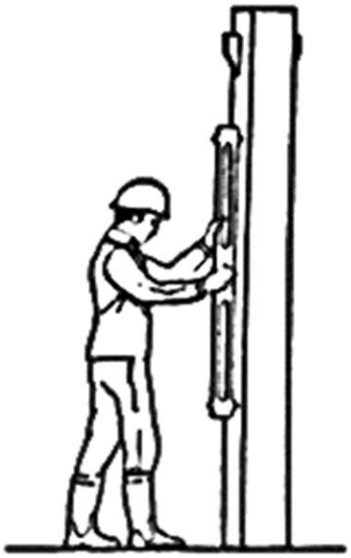


Fig 26.1 Plumbing a column by using a spirit level

Plumb-bob Methods

A simple example of plumbing is shown below where a wall is checked for verticality after a concrete pour. The plumb-bob is suspended from a length of timber nailed to the top of the formwork, and protected from the wind or immersed in a drum of oil or water.

Offset measurements are taken at the top and bottom of the formwork, and allowance made for any steps or tapers in the wall. A push-pull prop is used to make any adjustments.

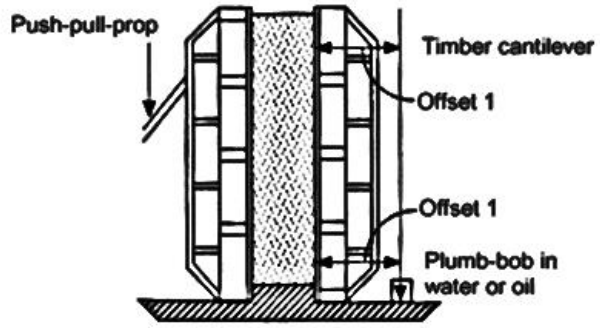


Fig 26.2

In multistorey structures plumb-bobs, usually weighing 3kg and suspended on adjustable reels of piano wire, are used.

The lift well is often a good site for a permanently suspended plumb-bob, since it can be placed to one side of the well and suspended in a drum of heavy oil at ground level.

In this way, it will be available for checking at floor level, and can be simply extended as the building rises. At least two plumb-bobs are required in order to provide a reference line from which the upper floors are controlled.

A reference mark is placed on the ground floor slab and the suspended plumb-bob moved until it is centred over the mark. Small holes must be left in the floor at each level so that the plumb lines can be extended as the building progresses, or used to check offsets for verticality as required.

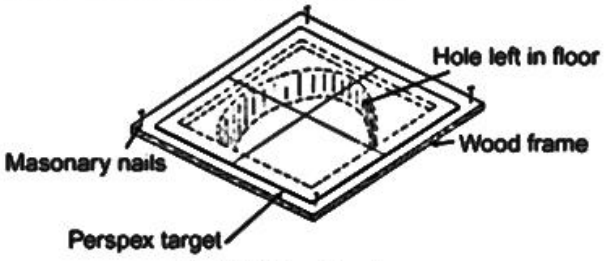


Fig 26.3 Centring frame

A centring frame is necessary to cover the opening and to enable the exact point to be fixed. The method is time-consuming and wind currents can be a problem.

Theodolite or Total Station Method

During construction the vertical columns of any structure must be truly vertical. If the building is more than one story, this will usually be achieved by observations from a theodolite or total station.

Special marks are placed on each face of the column at the top and near the base such that, when the column is truly vertical each set of marks will fall in a vertical plain.

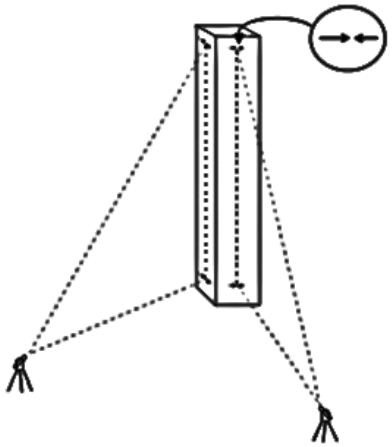


Fig 26.4 Plumbing the centre line of a column

The example below shows the formwork for a tall column form being plumbed. The theodolite is set up on a parallel offset to one face, and sighted to offset marks at the top. Both edges are observed to check on twist.

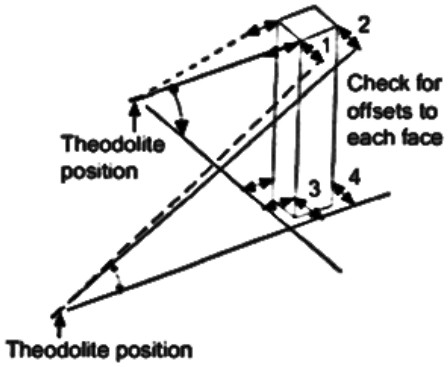


Fig 26.5 Theodolite observations by offsets

Similar observations are made on the bottom of the form. The mean of face left and face right observations is used. Any discrepancy in verticality is read at the bottom for convenience and the adjustment made to the column form accordingly.

The complete process is then repeated for the adjustment column face. A diagonal eyepiece for the theodolite may be used for the sighting of steep angles.

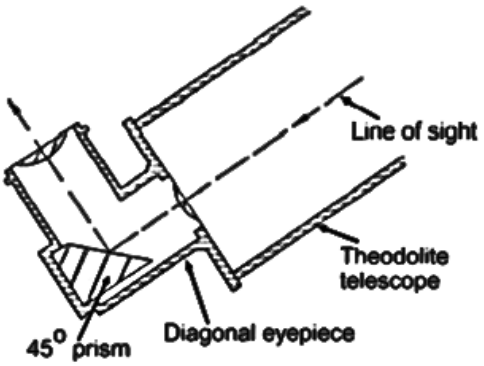


Fig 26.6 Diagonal eyepiece

For accuracy, the theodolite should be at some distance from the column, although this may be difficult on a cramped site.

The same principles apply in the case of a large multi-storeyed structure where control needs to be transferred to the various floors. The theodolite is set up on each alignment of the original control references marked on the ground floor slab - eight separate set-ups, as shown in the figure below.

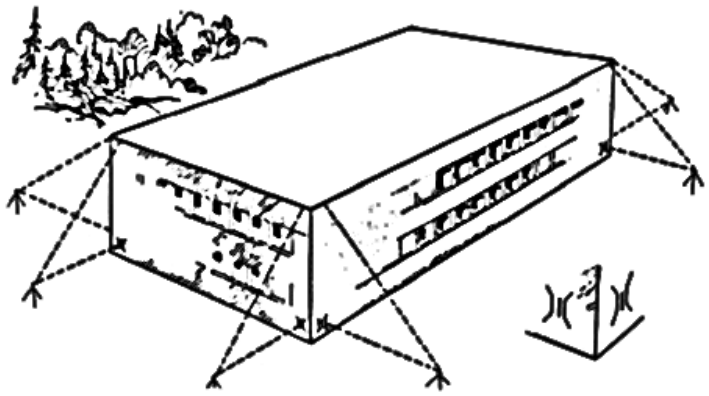


Fig 26.7

A sighting is made face left onto the line being transferred and the telescope elevated to the required floor and a point marked on the face of that floor. The procedure is repeated on face right. If the theodolite is in good adjustment the two marks will coincide. If not, the mean position is adopted. After transfer of all eight marks, a check is obtained by joining and measuring between them.

Optical Plumbing Methods

The auto-plumb or optical plummet is a specially designed survey instrument that allows plumbing upwards from a ground mark or downwards from a point overhead.

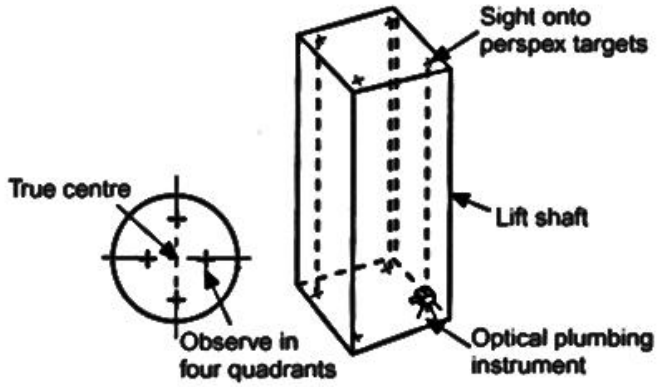


Fig 26.8 Upwards plumbing

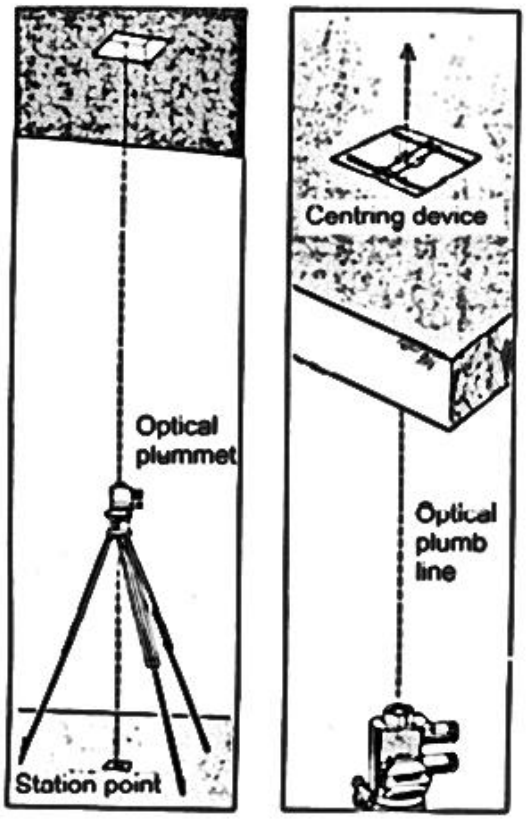


Fig 26.9 Upwards plumbing

Optical plumbing is particularly useful for lift shafts, where the plumbing is a particularly critical operation because the installation tolerances are small. In the example below the use of an optical plumbing instrument in a lift shaft is shown, with at least three ground stations being used to check for possible twisting.

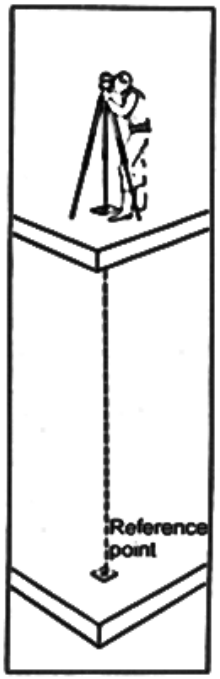


Fig 26.10 Downwards plumbing

More notes on the topic

10.6 CONTROLLING VERTICALITY

10.6.1 Using a plumb-bob

In low-rise construction a heavy plumb-bob (5 to 10 kg) may be used as shown in *Figure 10.13*. If the external wall was perfectly vertical then, when the plumb-bob coincides with the centre of the peg, distance *d* at the top level would equal the offset distance of the peg at the base. This concept can be used internally as well as externally, provided that holes and openings are available.

10.6.2 Using a theodolite

If two centre-lines at right angles to each other are carried vertically up a structure as it is being built, accurate measurement can be taken off these lines and the structure as a whole will remain vertical. Where site conditions permit, the stations defining the 'base figure' (four per line) are placed in concrete well clear of construction (*Figure 10.14(a)*). Lines stretched between marks fixed from the pegs will allow offset measurements to locate the base of the structure. As the

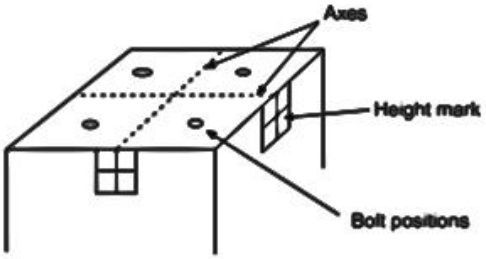


Fig. 10.12

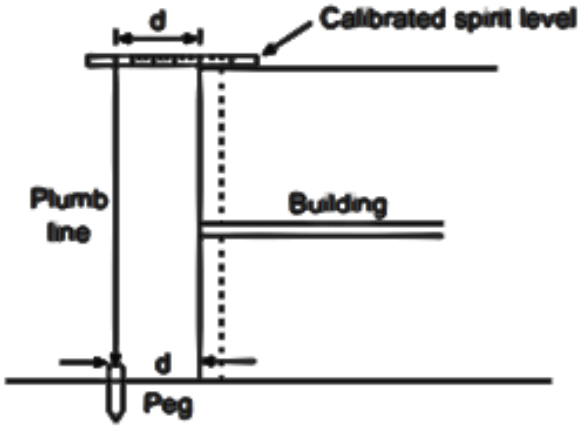
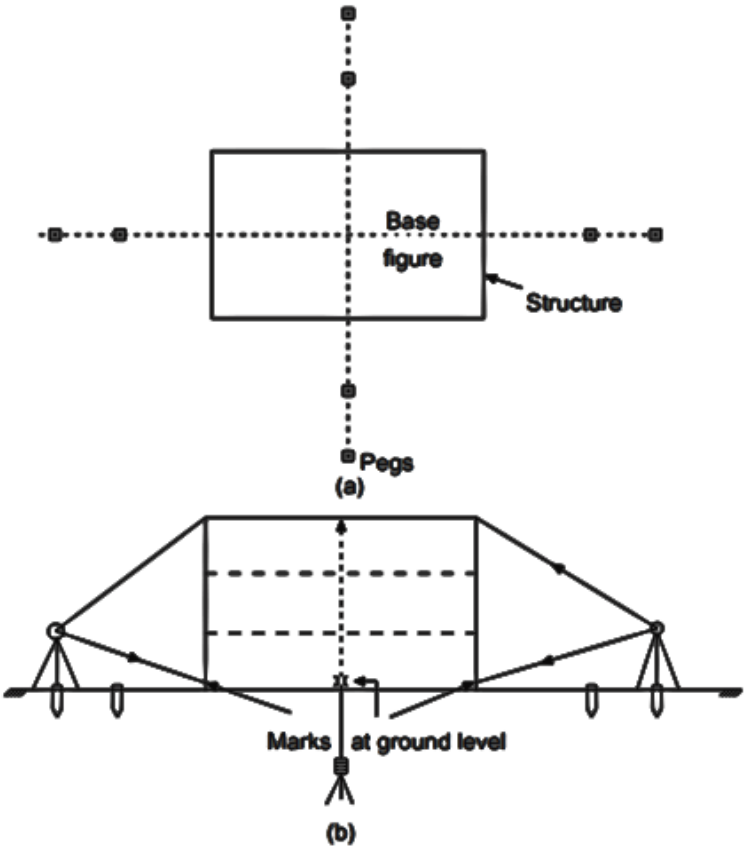


Fig. 10.13



structure rises the marks can be transferred up onto the walls by theodolite, as shown in *Figure 10.14(b)*, and lines stretched between them. It is important that the transfer is carried out on both faces of the instrument.

Where the structure is circular in plan the centre may be established as in *Figure 10.14(a)* and the radius swung out from a pipe fixed vertically at the centre. As the structure rises, the central pipe is extended by adding more lengths. Its verticality is checked by two theodolites (as in *Figure 10.14(b)*) and its rigidity ensured by supports fixed to scaffolding.

The vertical pipe may be replaced by laser beam or autoplumb, but the laser would still need to be checked for verticality by theodolites.

Steel and concrete columns may also be checked for verticality using the theodolite. By string lining through the columns, positions $A - A$ and $B - B$ may be established for the theodolite (*Figure 10.15*); alternatively, appropriate offsets from the structural grid lines may be used. With instrument set up at A, the outside face of all the uprights should be visible. Now cut the outside edge of the upright at ground level with the vertical hair of the theodolite. Repeat at the top of the column. Now depress the telescope back to ground level and make a fine mark; the difference between the mark and the outside edge of the column is the amount by which the column is out of plumb. Repeat on the opposite face of the theodolite. The whole procedure is now carried out at B. If the difference exceeds the specified tolerances the column will need to be corrected.

10.6.3 Using optical plumbing

For high-rise building the instrument most commonly used is an autoplumb (*Figure 10.16*). This instrument provides a vertical line of sight to an accuracy of ±1 second of arc (1 mm in 200 m). Any

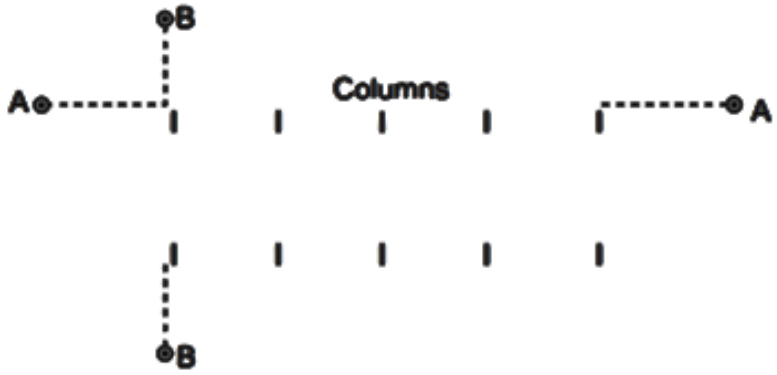


Fig. 10.15

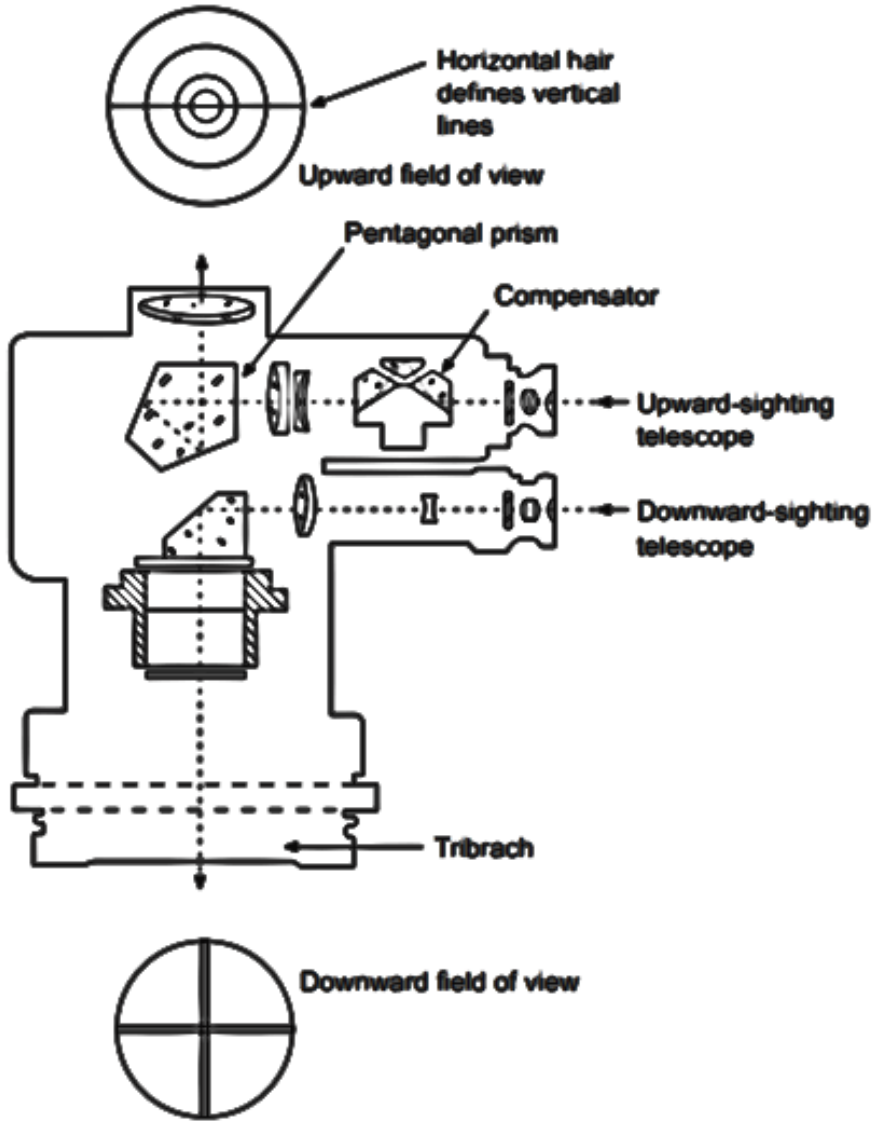


Fig. 10.16 *The optical system of the autoplumb*

deviation from the vertical can be quantified and corrected by rotating the instrument through 90° and observing in all four quadrants; the four marks obtained would give a square, the diagonals of which would intersect at the correct centre point.

A base figure is established at ground level from which fixing measurements may be taken. If this figure is carried vertically up the structure as work proceeds, then identical fixing measurements from the figure at all levels will ensure verticality of the structure (*Figure 10.17*).

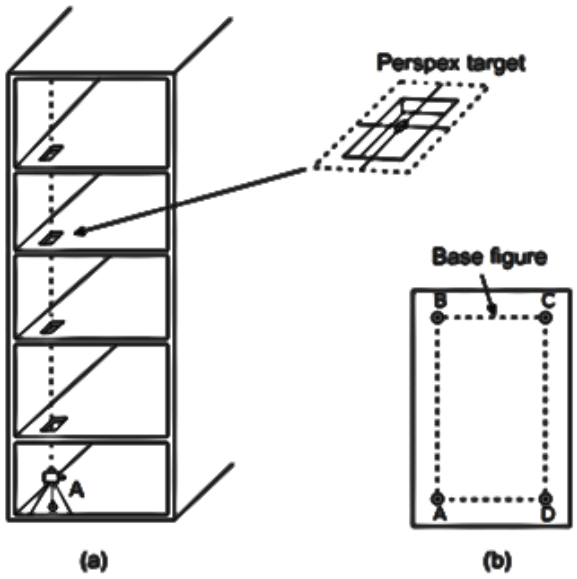


Fig. 10.17 *(a) Elevation, and (b) plan*

To fix any point of the base figure on an upper floor, a Perspex target is set over the opening and the centre point fixed as above. Sometimes these targets have a grid etched on them to facilitate positioning of the marks.

The base figure can be projected as high as the eighth floor, at which stage the finishing trades enter and the openings are closed. In this case the uppermost figure is carefully referenced, the openings filled, and then the base figure re-established and projected upwards as before.

The shape of the base figure will depend upon the plan shape of the building. In the case of a long rectangular structure a simple base line may suffice but *T* shapes and *Y* shapes are also used.

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