INSTRUCTION MANUAL

NORMAL PLUMB LINE AND
INVERTED PLUMB LINE

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PLUMB LINE

General Description

Plumb Lines are used in Dams for the measurement and monitoring of relative displacement between:

a. Dam top and the base
b. Base and the foundation rock

The displacement is measured in the inspection gallery on an observation table generally mounted with two traveling telescopes. It should be obvious that these plumb lines are not as simple as ordinary plumb lines used by construction workers. Great care should be taken in the mounting of this sophisticated equipment and in their subsequent maintenance and care.

Two type of plumb line assemblies are available:

I. Normal Plumb Line Assembly

This assembly is used when the displacement between the top and the base of the Dam is to be measured and monitored. The upper end of the plumb line wire is fixed through a collet arrangement, centered on a suspension spider which sits on a flange, grouted at the top of the Dam. A heavy weight of around 10 kg is clamped to the lower end of the wire. The weight hangs in a tank filled with oil. The oil in the tank acts as a damping medium and prevents any to and fro oscillatory movement of the plumb due to any vibration or shocks. Atilt in the Dam brings about a shift in the weight which is measured by a set of traveling telescopes mounted perpendicular to each other on the observation table. For taking the zero readings of the traveling telescopes, two reference plumbs are respectively mounted opposite to them on the observation table.

II. Inverted Plumb Line Assembly

This assembly is used when the displacement between the base of the Dam and the rock foundation is to be measured and monitored. A hole of 150 mm or more in diameter is drilled from the gallery to the desired depth up to the foundation rock. One end of the plumb wire is attached to a steel anchor with the help of a collate. The steel anchor is centered and grouted at the bottom of the hole. The upper end of the steel wire is fastened by a collate to a float submerged in a water tank in the gallery. A tension of around 8 kg is maintained in the plumb wire. The water in the tank acts as a damping medium and prevents any to and fro oscillatory movement of the pendulum due to any vibration or shocks. A tilt or displacement in the foundation brings about a shift in the float which is measured by a set of traveling telescopes mounted perpendicular to each other on the observation table. For taking the zero readings of the two traveling telescopes, two reference plumbs are respectively mounted opposite to them on the observation table.

Measurement of the displacement is done by asset of two traveling telescopes mounted at right angles to each other. It is recommended that two traveling telescopes (one each for the X and Y axes) be ordered. This adds a little to the cost, but obviates the necessity of moving and re-aligning the telescope, plumb line and reference plumb every time a reading has to be taken for the X and Y axes. Two traveling telescopes not only cut short the observation time but also minimize any chance of error. The use of two independent telescopes for the X and the Y directions is recommended. In installations done by SME, the X and Y axes are aligned with the longitudinal and transverse axes of the Dam.

INSTALLATION PROCEDURE FOR INVERTED PLUMB LINE

1. General

Figure no.1 provides the general cross- sectional layout of the inverted plumb line. It provides the details for mounting the water tank in its position, fixing the observation table and mounting the telescopes and reference plumbs.

The plumb line installation is carried out after completion of the civil work. Great care is to be exercised during the execution of the civil work. The following precautions must be observed:

a. Sufficient space should be available in the observation gallery for the fixing of the observation table and for t5he technician to sit by the sides of the table and take the readings. It is also essential that to and fro movement in the observation gallery does not get restricted. This makes it necessary to widen the observation gallery at the location where the inverted plumb line is located. In a number of Dams, the inverted plumb line has been installed in the extra space made available by cutting the corner at the intersection of the longitudinal and cross galleries.

b. The observation table has a dimension of 1 m X m with a 300 mm hole through which the plumb line passes. This hole is not in the middle of the observation table. Its center is at 350 mm from the two edges. Any layout should make sure that this hole should be concentric with the vertical drilled hole in the Dam foundation through which the inverted plumb line passes.

c. Depending upon the depth to the foundation rock from the observation gallery, a vertical hole of minimum 150 mm diameter has to be drilled. Larger the depth, larger should be the diameter of the hole.
This vertical hole which interconnects the base gallery to the foundation rock should be plumb within close limits such that the inverted plumb line in its two extreme positions does not foul with the sides.

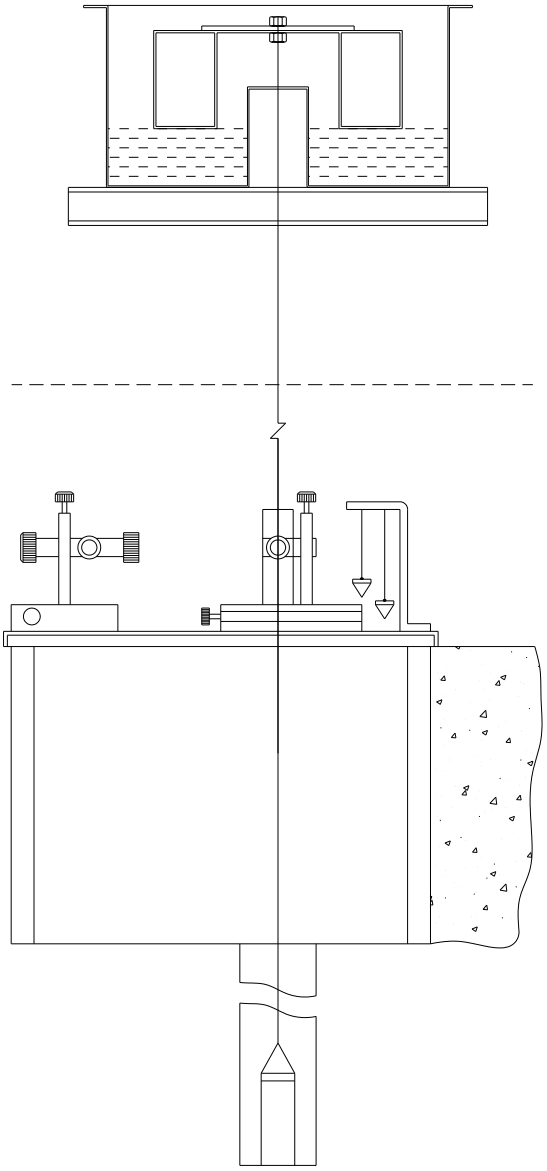


FIGURE NO.1

d. The overhead tank and the float are to be mounted the observation table. They require a minimum space of 1-1.5 m in height above the channels on which the water tank is placed.

2. Installation Procedure

After completion of civil work proceed with the inverted plumb line installation as follows.

a. Fixing of Tank Support Channels:

Hang an ordinary plumb from the gallery ceiling such that its center alignment with the center of the drilled hole at the bottom of the observation gallery. Grout two base frames consisting of 150 X 150 mm angles, 750 mm long at the requisite height on the two sides of the ordinary plumb. Position the two 125 X 65 mm MS channels across the

width of the gallery on the pre-grouted base frames such that they are parallel to each other and at a distance of 250 mm each from the ordinary plumb line. Fix the channels to the base frames by welding or through fasteners.

b. Positioning of Observation Table

Position the mild steel observation table on the four 200 mm square 0.8 m high concrete columns or the rigid mild steel framework such that the hole 300 mm hole in the observation table is approximately above the vertical hole drilled from the gallery.

c. Positioning of Water Tank & Float on the MS Channels

Position the water tank on the fixed channels such that its center hole is approximately concentric with the 300 mm hole in the observation table below. Fill water in the tank up to a level of around 200 mm. Place the float in the water tank.

d. Lowering of Anchor & Fixing it in Position

Determine the approximate length of the stainless steel wire from the top of the collet in the float to the bottom of the drilled hole. Make an extra allowance to about 2 m and cut the wire. Thread one end of the wire through the anchor collet from the collet side and secure the end of the wire firmly to the anchor screw provided on the anchor. Cut a mild steel disc of diameter around 5 mm less than the drilled hole. Fix it concentric with the anchor to its bottom by epoxy or by welding. Gradually lower the anchor with its attached disc into the vertical hole to its bottom. The disc helps in centering the plumb line in the drilled hole. Lower a PVC pipe into the drilled hole and pump in the requisite amount of mortar to set the anchor in position.

e. Fixing of Water Tank

Pass the other end of wire through the 300 mm hole in the observation table and through the collet on the float. Tighten the collet, maintaining a tension on the plumb wire such that the float is submerged in water up to the marked level. This will result in a tension of about 8 kgf on the plumb wire. During tightening of the collet on the float use a set of spanners. Use of two spanners during the tightening of the collet is recommended to avoid any joke or undue force which may damage the float. Tension the wire and secure it firmly around the anchor screw provided on the float. Check the concentricity of the float with the walls of the water tank. Make minor adjustments by shifting the water tank on the fixed channels. Permanently fix the water tank on the channels through fasteners or by welding, after the float becomes concentric with the water tank.

f. Grouting of the Observation Table on to the Concrete Pillar

Shift the observation table to the center the inverted plumb line inside the 300 mm hole on the observation table. Align the edges of the table such that they are parallel to the two perpendicular directions in which the tilt of the dam with respect to the foundation is to be measured. This will ascertained that the vernier scales on the traveling telescopes will be aligned with the longitudinal and transverse axes and will correctly measure the deflection of the dam in the two perpendicular directions. The observation table should now be firmly grouted in place by using the expansion fasteners provided along with the equipment. Use a 16 mm carbide tipped drill bit to drill four 10 cm deep holes through the mounting holes on the observation table. These mounting holes are at a center distance of 880 mm X 880 mm. During the process, do not disturb the position of the observation table. Place the expansion fasteners (thread side up) in the holes, one at a time and tighten them with a spanner to expand them and be firmly seated in the drilled holes. The threaded portion of the expansion fasteners should be around 20 mm above the observation table. Tighten the observation table in position by using the supplied nuts and washers.

For alternatively mounting the observation table on mild steel rigid supports, an additional set of three holes each have been provided on the observation table___

3. Positioning, Operation and Care of the Traveling Telescope

The traveling telescope is packed with its accessories in a specially designed case. The accessories consist of leveling screws with nuts, a spirit level & a magnifying glass. Mount the leveling screws with their nuts in the holes provided on the two telescope bases. Position the two telescopes on the observation table such that the front edge butts with the reference plate

and the left edge touches the reference pin. Level the traveling telescopes with the help of the spirit level provided.

The traveling telescope consists of a heavy aluminium base which is provided with a sliding mechanism which permits the vertical pillar to be moved across the base along the horizontal vernier scale. To slide the pillar the knurled set screw provided on its base should be loosened so as to disengage it. This arrangement provides the coarse setting to be made. For finer adjustment of the telescope barrel in the horizontal axis, the knurled knob referred to above should be tightened fully and the movement accomplished by rotating the large knurled knob provided on the right hand side on the telescope. The barrel of the telescope can also be moved up & down in the vertical plane by loosening the allen screw provided on the bracket on the vertical pillar. A focusing knob is provided on the right hand side of the telescope barrel.

A cross can be seen through the eye piece. Provision for rotating the cross and aligning it vertically with the inverted plumb line is available in the eye piece. For ease in alignment the objective lens can be rotated to slightly shift the vertical axis. The traveling telescope can focus between 350 mm and 900 mm from the end of the objective lens. It is preferable to install it in the rear position of the bracket on the vertical pillar.

Due care of telescopes should be taken. They should be kept covered with a plastic dust cover. Lenses should be cleaned periodically with a camel hair brush and lens cleaner available from any good photographic dealer. Telescopes require gentle handling and should be given the care and protection generally given to quality optical equipment.

4. Reference Plumb Setting

The reference plumbs provide a permanent reference point for the transverse and longitudinal measurements. The deflection of the inverted plumb line will be measured with respect to these permanent reference plumbs.

Each reference plumb is provided with two plumb line bobs hanging from strings. Mount the reference plumbs with the plumb line bobs facing the traveling telescopes in the holes provided on the observation table. Apply a coat of two component water proof epoxy between the observation table and the base of the reference plumbs. Adjust one of the reference plumb by moving it sideways and rotating it so as to align the threads of the two plumb line bobs in a straight line with the vertical line of the cross, of the telescope. Tighten the reference plumb into position. Let the epoxy set such that the reference plumb becomes an integral part of the observation table. This setting should never be distributed.

Fix the other reference plumb to the observation table in the same manner.

NOTE: The reference plumb provides a permanent reference point for all future measurements. The reference plumb is to be fixed once and for all and is not to be moved/ removed/ or dismantled under any circumstances at any later stage.

5. Taking Initial Reading In Transverse Direction

Loosen the horizontal movement coarse adjustment knob on the telescope base. Slide the telescope vertical pillar side ways so as to coarse align the vertical cross wire within the telescope barrel with the two threads of the reference plumb. Lock the coarse adjustment knob. Fine align the vertical cross wire with the reference plumbs using the right hand side fine adjustment knob. Note the vernier reading on the horizontal scale and enter it into the log book. Next, focus the telescope to the inverted plumb line and align the vertical cross wire to it. Take the new vernier reading and enter it in the log book. The difference between the two readings represents the initial position of the plumb line with respect to the permanent reference plumb.

For convenience, the telescope used for the transverse reading and the reference plumb opposite it, should be marked with the letter 'TI'. 'I' stands for Inverted.

6. Taking Initial Reading In Longitudinal Direction

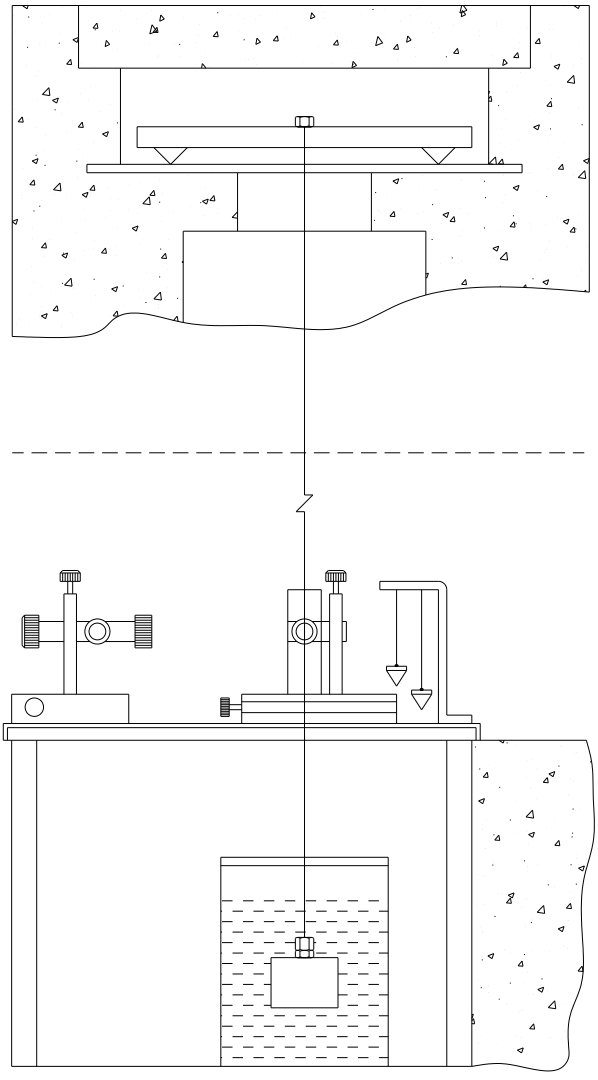
Repeat the procedure outlined above using the longitudinal traveling telescope and likewise enter the observations in the log book. For convenience, the telescope used for the longitudinal reading and the reference plumb opposite it, should be marked with the letter 'LI'.

7. Shift in Respect to Foundation Rock

In the event of shift of the Dam structure in respect to the foundation rock. The deflection of the plumb line can be accurately measured in both the transverse and the longitudinal directions by aligning the vertical cross wire with the reference plumb and then with the inverted plumb line and nothing the new vernier readings in the observation table.

8. Vertical Deflection

Any vertical movement of the observation gallery with respect to the foundation rock can also be monitored by the plumb line if a suitable mark is made on the plumb line wire and appropriate readings taken.



INSTALLATION PROCEDURE FOR NORMAL PLUMB LINE

The plumb line installation is carried out after completion of the civil work. The following precautions must be observed:

a. Sufficient space should be available in the observation gallery for the fixing of the observation table and for the technician to sit by the sides of the table and take the readings. It is also essential that to and fro movement in the observation gallery does not get restricted. This makes it necessary to widen the observation gallery at the location where the plumb line is located. In a number of dams, the plumb line has been installed in the extra space made available by cutting the corner at the intersection of the longitudinal and cross galleries.

b. The observation table has a dimension of 750 mm X 750 mm with a 300 mm hole through which the plumb line passes. This hole is not in the middle of the observation table. Its center is at 350 mm from the two edges. Any layout should make sure that this hole should be concentric with the vertical shaft in the dam through which the plumb line passes.
c. During the construction of the dam, a vertical steel/cement pipe is cast in position from the gallery to the top of the dam for the plumb line to pass through. Depending upon the height of the dam, the internal diameter of this vertical shaft should be anything between 300-500 mm. This vertical shaft which interconnects the top of the dam to the base gallery should be plumb within close limits such that the plumb line in its two extreme positions does not foul with the sides.

1. Installation procedure

a. Positioning of Observation Table

Position the mild steel observation table on the four 200 mm square 0.8 m high concrete columns or the rigid mild steel framework such that the hole 300 mm hole in the observation table is approximately below the vertical shaft. Place the oil tank below the 300 mm opening.

b. Fixing of Flange to Top End of Vertical Shaft

Grout flange at the top of the vertical shaft. Ensure that its top surface is level. Complete the civil work and allow the concrete to set firmly.

c. Placement of Spider and Lowering of Weight

Determine the approximate length of the stainless steel wire from the top of the flange to the bottom of the oil tank in the lower gallery. Make an extra allowance to about 2 m and cut the wire. Thread one end of the wire through the spider collet from the collet side. After the wire emerges from the lower surface (the side which has the three tapered guide pins to rest on top of the flange groove) of the spider, thread the weight by pushing the wire into the collet arrangement provided on the weight. the wire emerges through its lower end. Secure the end of the wire firmly to the anchor screw provided on the weight. Exert a tension on the wire by lifting the weight and tighten the collet provided on the weight by a set of spanners. Two people may be required to do this job.

Pass around a meter of the wire through the collet on the spider and tighten the collet to clamp the wire securely. Gently lift and position the spider/wire/weight assembly into the opening in the flange and lower it into the vertical shaft. Allow the tapered locating pins of the spider to rest in the groove on the flange top. Please note that the spider is a precision machined assembly which always centers the plumb wire in the same position with reference to the grouted flange.

Loosen the spider collet and gradually lower the weight into the vertical shaft, past the opening in the observation table to a depth of around 100 mm above the bottom of the oil tank in the observation gallery. Tighten the collet on the spider with as set of spanners. Use of two spanners during the tightening of the collet is recommended to avoid any jerks or undue force which may crack the web of the spider. Tension the wire and secure it firmly around the anchor screw provided on the spider plate.

d. Grouting of the Observation Table on to the Concrete Pressure

Shift the observation table to the center the inverted plumb line inside the 300 mm hole on the observation table. Align the edges of the table such that they are parallel to the

two perpendicular directions in which the tilt of the dam is to be measured. This will ascertained that the vernier scales on the traveling telescopes will be aligned with the longitudinal and transverse axes and will correctly measure the deflection of the dam in the two perpendicular directions. The observation table should now be firmly grouted in place by using the expansion fasteners provided along with the equipment. Use a 16 mm carbide tipped drill bit to drill four 10 cm deep holes through the mounting holes on the observation table. These mounting holes are at a center distance of 88 cm X 88 cm. During the process, do not disturb the position of the observation table. Place the expansion fasteners (thread side up) in the holes, one at a time and tighten them with a spanner to expand them and be firmly seated in the drilled holes. The threaded portion of the expansion fasteners should be around 20 mm above the observation table. Tighten the observation table in position by using the supplied nuts and washers.

For alternatively mounting the observation table on mild steel rigid supports, an additional set of three holes each have been provided on the observation table.

e. Filling of Oil Tank

Obtain requisite quantity of SAE 30 or 40 Mobil oil and fill up the oil tank such that the level of oil is approximately 5-6 cm above the surface of the hanging weight. the capacity of the oil tank is around 50 liters.

2. Positioning, Operation and Care of the Traveling Telescopes

The traveling telescope is packed with its accessories in a specially designed case. The accessories consist of leveling screws with nuts, a spirit level & a magnifying glass. Mount the leveling screws with their nuts in the holes provided on the two telescope bases. Position the two telescopes on the observation table such that the front edge butts with the reference plate and the left edge touches the reference pin. Level the traveling telescopes with the help of the spirit level provided.

The traveling telescope consists of a heavy aluminum base which is provided with a sliding mechanism which permits the vertical pillar to be moved across the base along the horizontal vernier scale. To slide the pillar the knurled set screw provided on its base should be loosened so as to disengage it. This arrangement provides the coarse setting to be made. For finer adjustment of the telescope barrel in the horizontal axis, the knurled knob referred to above should be tightened fully and the movement accomplished by rotating the large knurled knob provided on the right hand side on the telescope. The barrel of the telescope can also be moved up & down in the vertical plane by loosening the allen screw provided on the bracket on the vertical pillar. A focusing knob is provided on the right hand side of the telescope barrel.

A cross can be seen through the eye piece. Provision for rotating the cross and aligning it vertically with the inverted plumb line is available in the eye piece. For ease in alignment the objective lens can be rotated to slightly shift the vertical axis. The traveling telescope can focus between 350 mm and 900 mm from the end of the objective lens. It is preferable to install it in the rear position of the bracket on the vertical pillar.

Due care of telescopes should be taken. They should be kept covered with a plastic dust cover. Lenses should be cleaned periodically with a camel hair brush and lens cleaner available from any good photographic dealer. Telescopes require gentle handling and should be given the care and protection generally given to quality optical equipment.

3. Reference Plumb Setting

The reference plumbs provide a permanent reference point for the transverse and longitudinal measurements. The deflection of the inverted plumb line will be measured with respect to these permanent reference plumbs.

Each reference plumb is provided with two plumb line bobs hanging from strings. Mount the reference plumbs with the plumb line bobs facing the traveling telescopes in the holes provided on the observation table. Apply a coat of two component water proof epoxy between the observation table and the base of the reference plumbs. Adjust one of the reference plumb by moving it sideways and rotating it so as to align the threads of the two plumb line bobs in a straight line with the vertical line of the cross, of the telescope. Tighten the reference plumb into position. Let the epoxy set such that the reference plumb becomes an integral part of the observation table. This setting should never be distributed.
Fix the other reference plumb to the observation table in the same manner.

NOTE: The reference plumb provides a permanent reference point for all future measurements. The reference plumb is to be fixed once and for all and is not to be moved/ removed/ or dismantled under any circumstances at any later stage.

4. Taking Initial Reading in Transverse Direction

Loosen the horizontal movement coarse adjustment knob on the telescope base. Slide the telescope vertical pillar side ways so as to coarse align the vertical cross wire within the telescope barrel with the two threads of the reference plumb. Lock the coarse adjustment knob. Fine align the vertical cross wire with the reference plumbs using the right hand side fine adjustment knob. Note the vernier reading on the horizontal scale and enter it into the log book. Next, focus the telescope to the dam plumb line and align the vertical cross wire to it. Take the new vernier reading and enter it in the log book. The difference between the two readings represents the initial position of the plumb line with respect to the permanent reference plumb.
For convenience, the telescope used for the transverse reading and the reference plumb opposite it, should be marked with the letter ‘TU’. ‘U’ stands for upright or normal.

5. Taking Initial Reading in Longitudinal Direction

Repeat the procedure outlined above using the longitudinal traveling telescope and likewise enter the observations in the log book. For convenience, the telescope used for the longitudinal reading and the reference plumb opposite it, should be marked with the letter ‘LU’

6. Dam Axis Shift

In the event of dam axis shift, the deflection of the plumb line can be accurately measured in both the transverse and the longitudinal directions by aligning the vertical cross wire with the reference plumb and then with the dam plumb line and noting the new vernier readings in the observation table.

7. Vertical Deflection

Any vertical movements in the dam structure can also be monitored by the plumb line if a suitable mark is made on the plumb line wire and appropriate readings taken.

OBSERVATION TABLE

Date	Sl.no.	Transverse Reading mm				Longitudinal reading mm			
		Ref. Plumb	Plumb line	XB-XA	XC-1C	Ref. Plumb	Plumb line	XF-XE	XG-1G
	X/Y	A	B	C	D	E	F	G	H
	1								
	2								
	3								
	4								
	5								
	6								
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