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USERS' MANUAL

DIGITAL INCLINOMETER SYSTEM OVERVIEW AND INSTALLATION

MODEL EAN-26

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Contents

1 INTRODUCTION

The EAN-26 inclinometer system is used for reliable measurement of lateral movement in applications like:

- Earth movement in landslide zone.
- Detecting shear planes in hydraulic structures.
- Measuring stability during construction.
- Deflection of diaphragm/retaining walls and piles under load.

The inclinometer system provides significant quantitative data on magnitude of inclination and its variation with time. It gives information on pattern of deformation and effectiveness of construction control measures. It helps in monitoring behaviour after construction and indicates potentially dangerous conditions that may adversely affect stability of the structure, its foundation and surrounding area. It also provides basic data for design improvement that will promote safer and economical design and construction.

The EAN-26 digital inclinometer system is an accurate instrumentation system. Its readout has built-in data storage facilities and capability of transferring stored data to a computer. The inclinometer probe operates in a plastic grooved casing which may be "built-up" with embankment fill, inserted into boreholes or attached externally to structures or hillsides. The inclinometer casing may be installed with telescopic couplings as construction progresses providing opportunity for settlement measurements, or it may be installed with butt joints in drill holes in abutments or completed embankments if no significant settlement is anticipated.

1.1 Displacement measurement

For measurement of vertical displacement, magnetic targets may be fixed to access casing at selected points. Measuring settlement by using inclinometer casing has largely replaced the earlier method using separate settlement devices like the cross arm. The same installation is now used to measure settlement as well as lateral movement. For details refer to data sheet 1098 "Magnetic Extensometer System".

1.2 Casing storage

- Do not apply too much load or force on casing.
- Store all items in a proper place in a ventilated building under shade of a roof
- Do not warp or bend during storage.
- Avoid direct sunlight on plastic casing and accessories as it can cause deformation of casing.

1.3 Conventions used in this manual

WARNING! Warning messages calls attention to a procedure or practice, that if not properly followed could possibly cause personal injury.

CAUTION: Caution messages calls attention to a procedure or practice, that if not properly followed may result in loss of data or damage to equipment.

NOTE: Note contains important information and is set off from regular text to draw the users' attention.

1.4 General information

This users' manual is intended to provide you with sufficient information for installing and making optimum use of ABS inclinometer casing. The manual also contains instructions on how to set-up for lowering inclinometer probe into gage well for purpose of taking inclination readings.

NOTE: Installation personnel must have a background of good installation practices and knowledge of the fundamentals of geotechnics. Novices may find it very difficult to carry on the installation work. The intricacies involved in installation are such that even if a single essential but

apparently minor requirement is ignored or overlooked, the most reliable of instruments will be rendered useless.

A lot of effort has been made in preparing this instruction manual. However the best of instruction manuals cannot provide for each and every condition in the field, which may affect performance of the sensor. Also, blindly following the instruction manual will not guarantee success. Sometimes, depending upon field conditions, installation personnel will have to consciously depart from the written text and use their knowledge and common sense to find the solution to a particular problem.

This equipment should be installed, maintained and operated by qualified personnel. Any errors or omissions in installation, data or data interpretation are not the responsibility of Encardio-Rite Electronics Pvt. Ltd.

For details on how to operate the inclinometer readout unit (mobile phone), please refer to operating manual # WI 6002.103.

To make this manual more useful we invite your valuable comments and suggestions regarding any additions or enhancements. We request you to please let us know of any errors that are found while going through the manual.

1.5 How to use this manual

The manual is divided into a number of sections. Each section contains a specific type of information. The list given below tells you where to look for in this manual if you need some specific information.

For principle of operation: See § 2.1 'Operating principle'.

For inclinometer system manufactured by Encardio-rite: See § 2.2 'General description'.

For specifications of the probe and data logger: See § 3 'system specifications'.

For essential tools and accessories: See § 4 'Tools and accessories required for installation'.

For installation of PVC casing: See § 5 'Installation of casing'.

For taking readings: See § 6 'Preparation for and obtaining readings'

2 INCLINOMETER SYSTEM

2.1 Operating principle

The first step is to make a near vertical gage well by installing casing in a borehole, embedding in an earth/rock fill or concrete structure during construction or fixing to face of a completed structure. The inclinometer probe is then passed through entire length of gage well, taking readings at fixed pre-determined depths from bottom to top. A dual accelerometer probe senses inclination of casing in two planes at right angles to each other. Voltage output from probe is directly proportional to sine of angle of inclination of long axis of probe from the vertical. A positive output voltage indicates a negative angle of inclination.

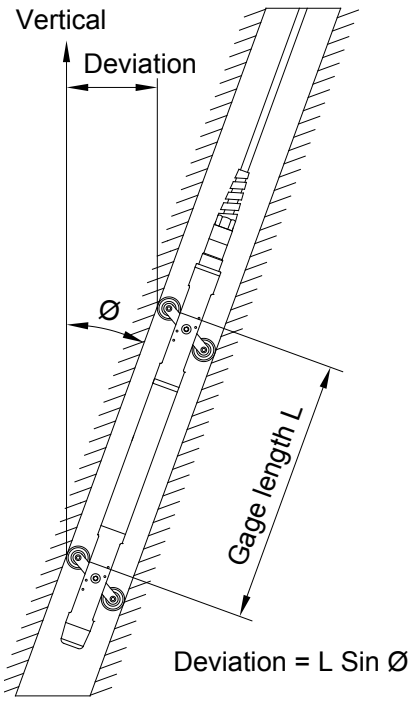


Figure 2.1

A set of initial base reading is taken at given depths within the gage well. This forms the reference datum. Subsequent reading sets are compared with this reference datum. All subsequent readings are taken over a period of time at identical depths, thereby indicating rate, magnitude, and direction of lateral deformation. The inclination is displayed in terms of angular or horizontal displacement (deviation) on the electronic readout equipment at ground level with the operator.

Provided that one end of access casing is known to be fixed, it is possible to obtain a complete profile of the gage well by taking a succession of readings. By comparing these profiles, the horizontal displacement of gage well at different depths over a period of time is determined.

2.2 General description - EAN-26 digital inclinometer system

The EAN-26 digital inclinometer system basically consists of:

- Access casing and fittings
- Tilt sensing probe
- Interconnecting cable with reel and cable holder
- Mobile phone datalogger

2.2.1 Access casing and fittings

2.2.1.1 EAN-AT70 ABS access casing (70 mm)

ABS access casing has longitudinal keyways, specially produced to close tolerances. Wheels of tilt sensing probe can run smoothly inside these keyways. It is self aligning ABS tubing, 70 mm o.d., 58 mm i.d., 3 m in length.

Figure 2.2 Inclinometer ABS casing

Two kinds of couplings are available to rapidly join access casing. Fixed couplings are normal and telescopic couplings are available in case settlement is expected to take place. The design of these couplings ensures that correct alignment of keyways is maintained throughout the depth of gage well.

2.2.1.2 EAN-FC70 ABS fixed coupling (70 mm)

77 mm o.d. ABS fixed coupling, 160 mm long, with four internal keyways at 90° to each other.

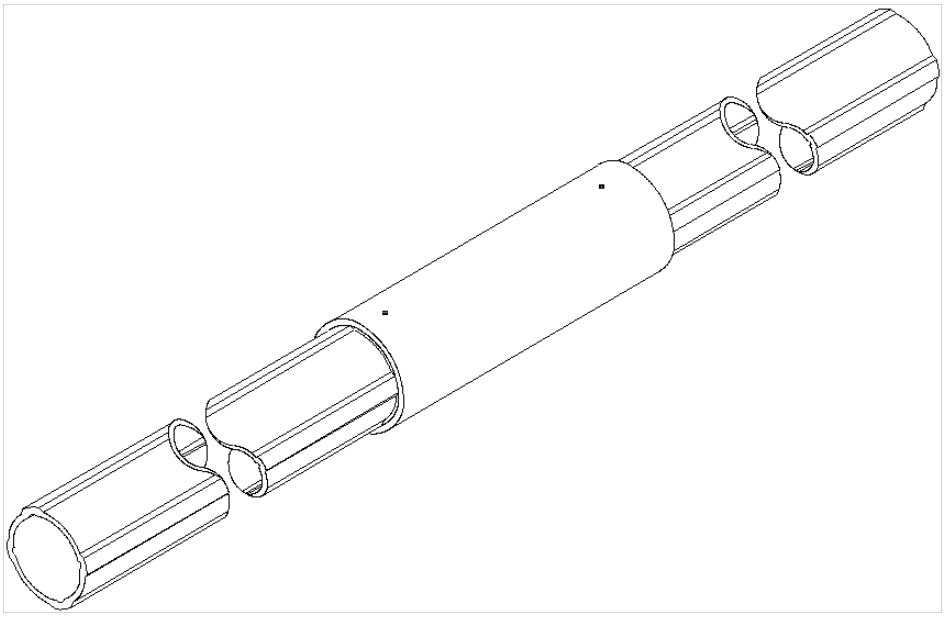


Figure 2.3 ABS casing with fixed coupling

2.2.1.3 EAN-TC70 ABS telescopic coupling (70 mm)

77 mm o.d. ABS telescopic coupling, 300 mm long, with four internal keyways at 90° to each other. Displacement 150 mm.

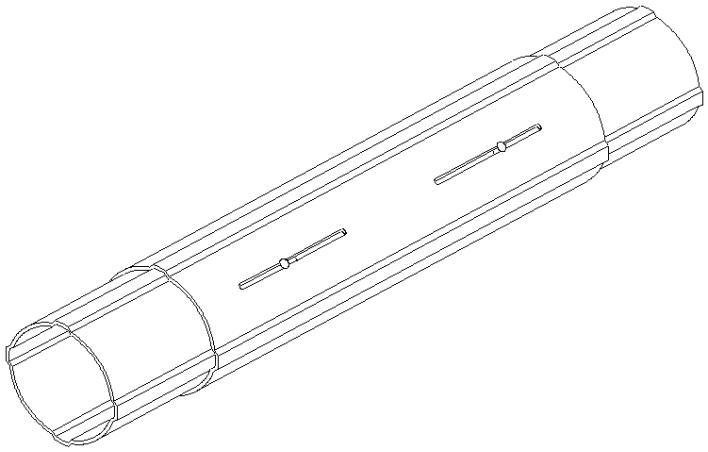


Figure 2.4 ABS casing with telescopic coupling

2.2.1.4 EAN-EC70 ABS end cap for access casing (70 mm)

ABS cap to fit 70 mm o.d. casing at top or bottom.

2.2.1.5 EAN-TT70 ABS top cap for access casing (70 mm)

ABS top cap with locking arrangement to fit 70 mm casing at top.

2.2.1.6 Pop rivets and self-taping screws for ABS casing

Pop rivets packets of 100 numbers for fixed coupling. Self-tapping screws packets of 100 numbers for telescopic coupling.

2.2.1.7 Pop rivet gun

Hand held manually operated.

2.2.1.8 Drill machine

Hand operated drill machine with two 3.2 mm diameter drill bits. Optionally a 230 V, 50 Hz operation power drill can also be used.

2.2.1.9 Mastic tape

50/100 mm wide x 10/5 m long

2.2.1.10 BOPP tape

50 mm wide x 65 m long BOPP waterproof sealing tape.

2.2.1.11 EAN-PC Protective cover unit

A lockable protective cover unit made of MS sheet and angle is available with extended Torr steel anchors for grouting at top of hole. The 150 x150 mm protective cover is provided with a hinged cover with lock with an interchangeable key. The cover is painted bright red in colour.

2.2.2 Digital inclinometer probe

2.2.2.1 EAN-26MV digital tilt sensing probe

The digital inclinometer (tilt sensig) probe measures angles of inclination from the vertical in two planes oriented at 90° (orthogonal) to each other. The inclinometer probe of stainless steel construction is fitted with two pairs of pivoted sprung wheels that can rotate freely. The standard gage length between the wheels is 500 mm (or 2 feet). The spring-loaded wheels help to accurately position the probe centrally inside the gage well at any required depth. The precision grooved casing forms an integral part of the gage well. The cylindrical portion of the probe has a diameter of 25.4 mm and a length of 685 mm.

The probe consists of two integral precision accelerometers, one with its axis in plane of the wheels and other at 90° to it. The probe senses horizontal deviation between the probe axis and the vertical plane, simultaneously in the 'X' and 'Y' directions.

A four pin connector is provided for connection to the cable.

Figure 2.5 inclinometer probe

2.2.2.2 EAN-DP Dummy probe

It has same dimensions as the actual probe. It is used for checking the gage well. Cord length is same as cable length in the actual probe.

2.2.3 Interconnecting cable with reel and cable holder

2.2.3.1 EAN-26R Cable reel with probe

Figure 2.6 cable reel with read-out

A cable reel is available for the specified length of cable.

A PU sheathed two core cable is clamped at every 0.5m (or 2 feet) with copper ferrules. The ferrules are number engraved at every meter.

A four pin connector is provided for connecting read-out to probe.

2.2.3.2 EAN-26CB Cable suspension bracket

It is directly placed on casing at top of gage well to lower probe into borehole. It has a slot to hold the cable

at the graduated marks (ferrules) for convenience in taking the readings (refer to figure 2.7).

2.2.4 EAN-26CCJ Calibration check jig

Calibration check jig enables verification of calibration of the inclinometer probe at known angles of tilt. Please refer to Users manual # WI 6002.107 R01 on how to mount and use calibration check jig.

2.2.5 Mobile phone datalogger

The Digital Inclinometer system uses Mobile Phone as a datalogger. Any mobile phone with minimum required features can be used for this application. Figure 2.7 is showing an example of Digital inclinometer application running on HTC Desire mobile phone. Phone is running on Android operating system for providing powerful platform to manage applications efficiently. It has so many features like phone calls, SMS, MMS, GPRS/3G, Wi-Fi, Bluetooth, USB and high resolution Camera. User can use it as mobile phone for making calls.

It has GPRS/3G which enables user to access internet from site to upload/download files and checking E-mails. Wireless Bluetooth can be used to send files to PC or any other Bluetooth device. High resolution camera can be helpful to take site conditions photographs and send them to the back office by sending MMS. It has higher capacity external memory card of 8GB which can store lots of data. Data backup can be taken on regular basis by connecting phone with PC through USB cable.

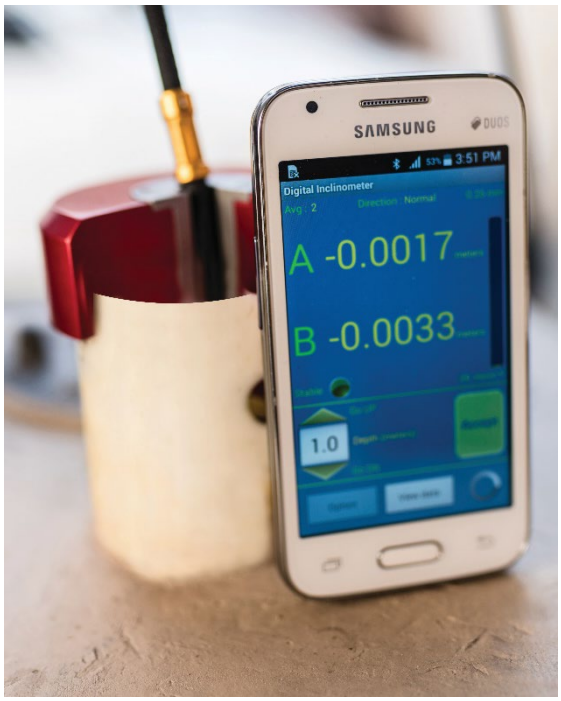


Figure 2.7 Read-out

The inclinometer software running on phone can take borehole readings and store them into memory. Inclinometer software has ability to show borehole logs in tabular format and create plots of borehole data instantly after borehole reading is complete. Borehole data files are created automatically while saving borehole log. These files can be recreated from software database when needed. Borehole files can be uploaded to remote server through GPRS/3G/Wi-Fi.

3 SYSTEM SPECIFICATIONS

3.1 Probe

	Metric	Imperial
Sensor	Dual accelerometer	Dual accelerometer
Distance between wheels	500 mm	24 inches
Probe Material	stainless steel	stainless steel
Probe Length	685 mm	31.3 inches
Probe Diameter	25.4 mm	1.0 inch
Measuring range	± 30 degrees	± 30 degrees
Data Resolution	0.007 mm per 500 mm	0.0004 inch per 24 inch
Axis Alignment	Digitally Nullified	Digitally Nullified
Operating temperature	-20 to 70°C	-20 to 70°C
Probe weight	1.4 kg	3.3 lbs

3.2 Cable reel

Outer sheath	Polyurethane	Polyurethane
Cable Diameter	6 mm	0.24 inches
Marking interval	0.5 meters	2.0 feet
Cable length	30 m, 50 m, 100 m, 150 m, 200 m, 300 m	100 ft, 150 ft, 200 ft, 300 ft
Battery	7.2V / 3000 mAh Li-ion	7.2V / 3000 mAh Li-ion
Weight	5.5 kg @ 30m cable	12 lbs @ 100 ft cable
Cable Weight	0.034 kg per meter	0.024 lbs per feet

3.3 Mobile phone datalogger (minimum requirements)

Due to continuous improvements and change in availability of models no specific recommendations can be made about manufacturer and model number. However, any mobile phone that is intended for use as readout unit for the digital inclinometer should have the following minimum features. If a mobile phone is ordered and supplied with the system it shall have the following minimum features.

OS Android OS, v2.2 (Froyo) or above

Display 4.0 inches, LCD touch screen, 480x800 pixels

Bluetooth v2.1 with A2DP

Memory 512 MB RAM,8 GB or above expandable memory with microSD card

Mobile Network 2G Network: GSM850/900/1800/190
3G Network: HSDPA900/2100
(If the mobile phone readout will be used in an area covered by CDMA network services only, then a mobile phone suitable for CDMA should be used or ordered)

3.4 Accessories (to be ordered separately)

- Dummy Probe
- Casing and fittings
- Installation accessories

- Probe calibration check frame
- Magnet assembly for inclinometer casing (if settlement measurement is also required)
- Magnetic settlement probe (if settlement measurement is also required)

4 TOOLS & ACCESSORIES REQUIRED FOR INSTALLATION

It should be ensured that following tools and accessories required for proper installation of the inclinometer PVC casing and for taking readings are available:

1 Tool box

2 50 mm wide water proof sealing tape

3 Spanner 16/18

4 Screw driver 100 mm

5 Voltage tester

6 Pliers 150 mm

7 Flat file 150 mm

8 Safety line or tension cable in case hole is very deep

9 Clean water supply to clean casing

10 Hand saw with three 30 cm blades

11 Casing collar protection if required

12 Grout tube - requisite length

13 Acetone

14 Aluminium pop rivets - four per joint plus some extra

15 Pop rivet gun

16 Drill with a 3.15 mm spare drill bit.

17 Casing clamps - 2 sets

18 Plumb bob with 5 m chord

19 Casing cap with guy ropes (for embankment installations)

20 Casing 'U' clamps and grout bolts (For installation on concrete structures)

5 INSTALLATION OF CASING

Following general instructions for installing ABS casing are typical practices in the field and may require modification to suit specific conditions and applications at site.

Inspect casing to ensure that damage in transit or storage has not occurred. See that ends and interior of casing are clean.

Store casing horizontally, fully supported and out of sunlight. This will prevent it from getting damaged or distorted. Number each length and assemble numerically to avoid errors and confirm correct depth.

CAUTION: Do not apply too much axial load on casing as it may damage casing by cracking. Also do not drop casing.

Casing may be installed in a borehole, embedded in an earth/rock fill or concrete structure during construction or fixed to vertical face of a completed structure. Installation on completed structure is not being described in this manual, as it is easy with help of casing clamps that may be separately procured.

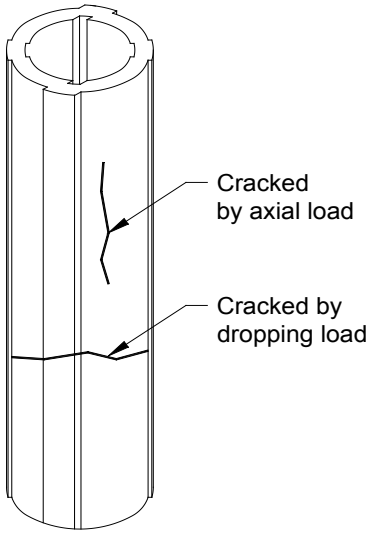


Figure 5.1 Checking of casing

5.1 Preparation of casing before installation

NOTE: Pre-assembly and storage of inclinometer casings should be done in shade as prolonged exposure to direct sun light might distort the tubes.

a. Clean inside of bottom cap and outside of lower end of a casing with moist cloth (use isopropyl alcohol if greasy).

b. Push bottom end cap over casing. Fix it to casing with four pop rivets using 3.2 mm diameter drill bit. Riveting should be done at diametrically opposite points 90° apart.

c. Seal joint between bottom cap and casing with mastic waterproof tape. One round of this tape with 10 mm overlap is sufficient. Press tape firmly after applying, to remove any air pocket.

d. Additionally wrap three to four rounds of BOPP tape with a little force over mastic tape for extra protection (refer to figure 5.2). Proper sealing is necessary to prevent intrusion of backfill materials inside casing.

5.1.1 Fixed coupling

a. Attach a fixed coupling each to one end of all other casings to be installed. Clean mating surfaces with moist cloth (use isopropyl alcohol if greasy).

Figure 5.2 Preparation of casing

b. Push 160 mm long fixed coupling over end of casing up to maximum allowable depth of around 80 mm. Drill holes with 3.2 mm bit and pop rivet coupling to casing at four places (position for two pop rivet holes are marked on coupling; other two holes should be symmetrically drilled).

c. Seal joint between fixed coupling and casing with mastic waterproof tape and BOPP tape as described above in § 5.1 (c) and 5.1 (d).

5.1.2 Telescopic coupling

Telescopic couplings are mostly installed in embankments where settlement takes place during construction. They are sometimes installed in boreholes also where settlement or heave may take place. Telescopic coupling has two sets of diametrically opposite longitudinal grooves which facilitate a total movement upto 150 mm (refer to figures 5.3 and 5.6). Coupling is secured to adjacent casings with a set of four screws and nylon washers.

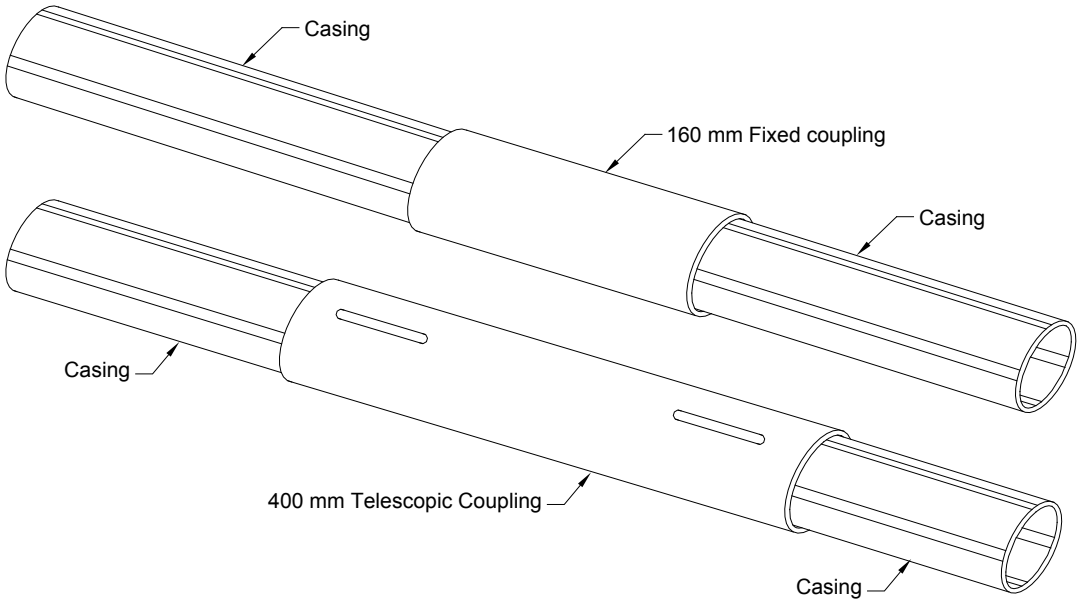


Figure 5.3 Fixed & telescopic couplings

a. Attach a telescopic coupling each to one end of all other casings to be installed excepting the one with the bottom cap. Clean mating surfaces with moist cloth (use isopropyl alcohol if greasy).

b. For applications in which only settlement takes place push 400 mm long telescopic coupling over end of casing upto maximum allowable depth of around 195 mm. Drill two holes with 2.5 mm bit at end of slot of coupling as shown in figures 5.4 and 5.5. Fix coupling to casing with self-tapping screws and washers at position A. (Position B is location where the other casing will be drilled during installation at site).

c. Pull casing out so that screw comes to position C as shown in figure 5.6. Tighten screws. Do not over tighten. When the other casing is finally assembled at site, a space of 150 mm will be left between the casing ends to take care of settlement.

d. In case settlement/ heave are both possible at location where casing is to be installed, adjust position of screws in groove for an appropriate length of travel as shown in figure 5.6. If such a casing is required to be lowered from top into a borehole, aluminium pop rivets may have to be used to keep coupling in position (refer to figure 5.7). Seal joint between telescopic coupling and casing with mastic waterproof tape and BOPP tape as described in § 5.1 (c) and 5.1 (d).

e. The casing assemblies are now ready for installation. Carefully transport them to site when required.

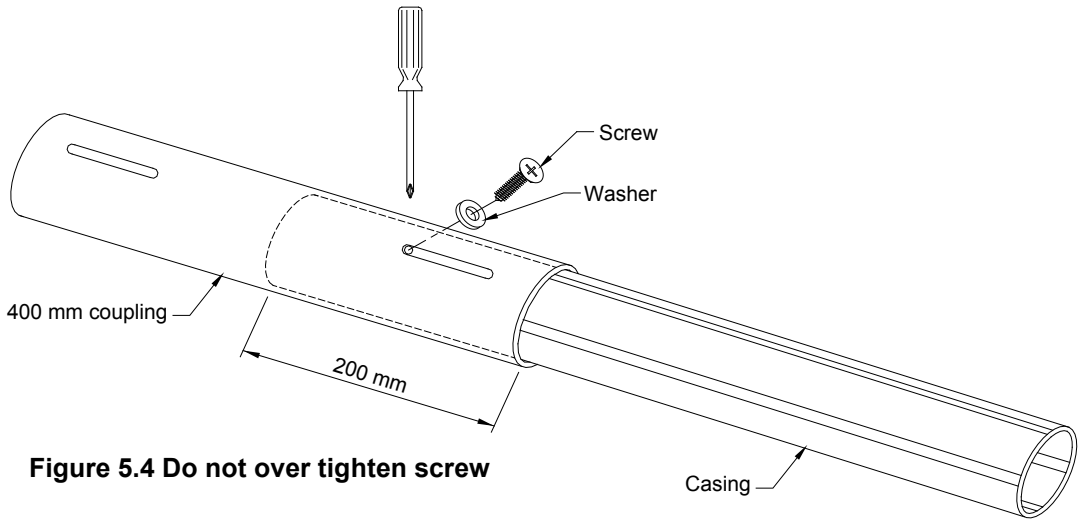


Figure 5.4 Do not over tighten screw

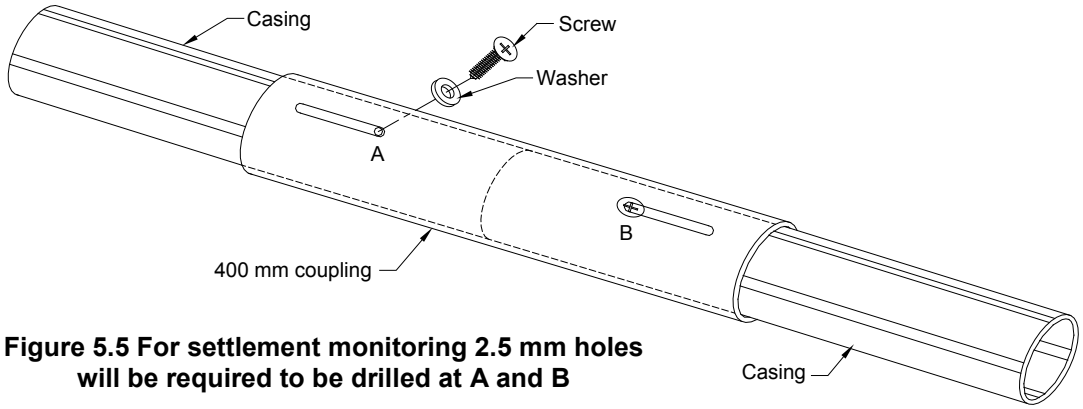


Figure 5.5 For settlement monitoring 2.5 mm holes will be required to be drilled at A and B

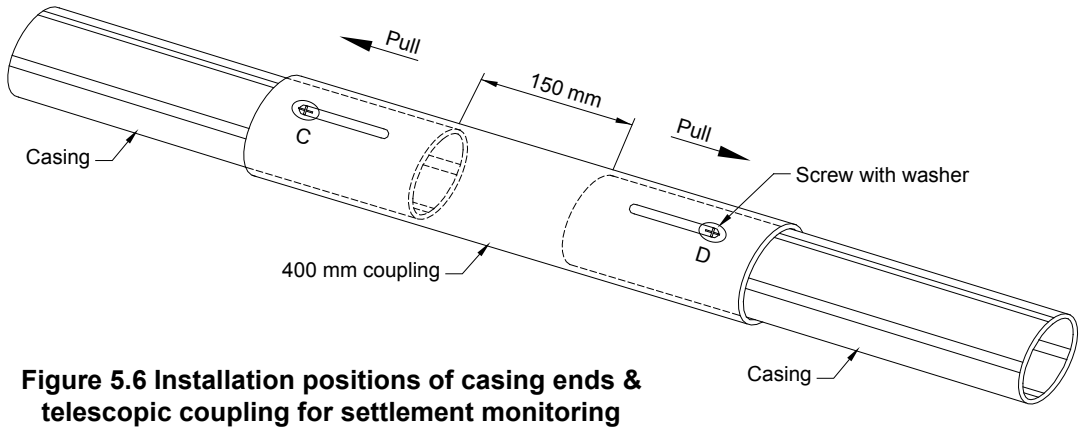


Figure 5.6 Installation positions of casing ends & telescopic coupling for settlement monitoring

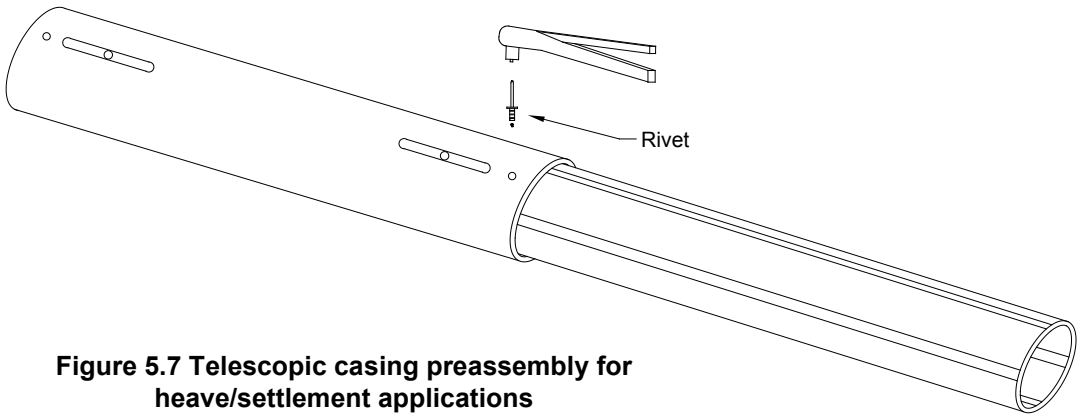


Figure 5.7 Telescopic casing preassembly for heave/settlement applications

5.2 Installation in borehole

5.2.1 Borehole drilling

a. Drill 125 mm diameter hole as vertical as possible around 0.5 m more than planned depth of inclinometer casing. The drill hole diameter should facilitate grouting around outside of casing. A mobile rotary drilling rig using rotary wash boring technique may be used to perform the drilling. Wash borehole clean and verify that it is not blocked anywhere upto bottom. To prevent sidewalls of borehole from collapsing, casing along with bentonite slurry may be used.

NOTE: If necessary, use suitable steel casing to prevent sidewalls of borehole from collapsing. In such a case, steel casing will have to be gradually withdrawn as grout is pumped into borehole.

NOTE: In case spider magnets are used around casing for settlement monitoring, drill hole diameter should preferably be 150 mm.

5.2.2 Installation of inclinometer casing in borehole

a. Lower casing with bottom cap into borehole gripping it with safety clamp secured around 500 mm from top.

NOTE: Maintain one pair of casing grooves perpendicular to direction in which lateral movement is to be measured. If no such direction is known, maintain one set of grooves parallel to N-S direction.

b. Take a casing pre-assembled with fixed coupling. Secure a safety clamp around 500 mm from its top end and mate coupling end with casing already lowered. Pop-rivet fixed coupling to casing at four places.

c. Seal joint with mastic waterproof tape and BOPP tape, as described in § 5.1 (c) and 5.1 (d).

d. Remove safety clamp from first casing and lower jointed casings into guide pipe/borehole.

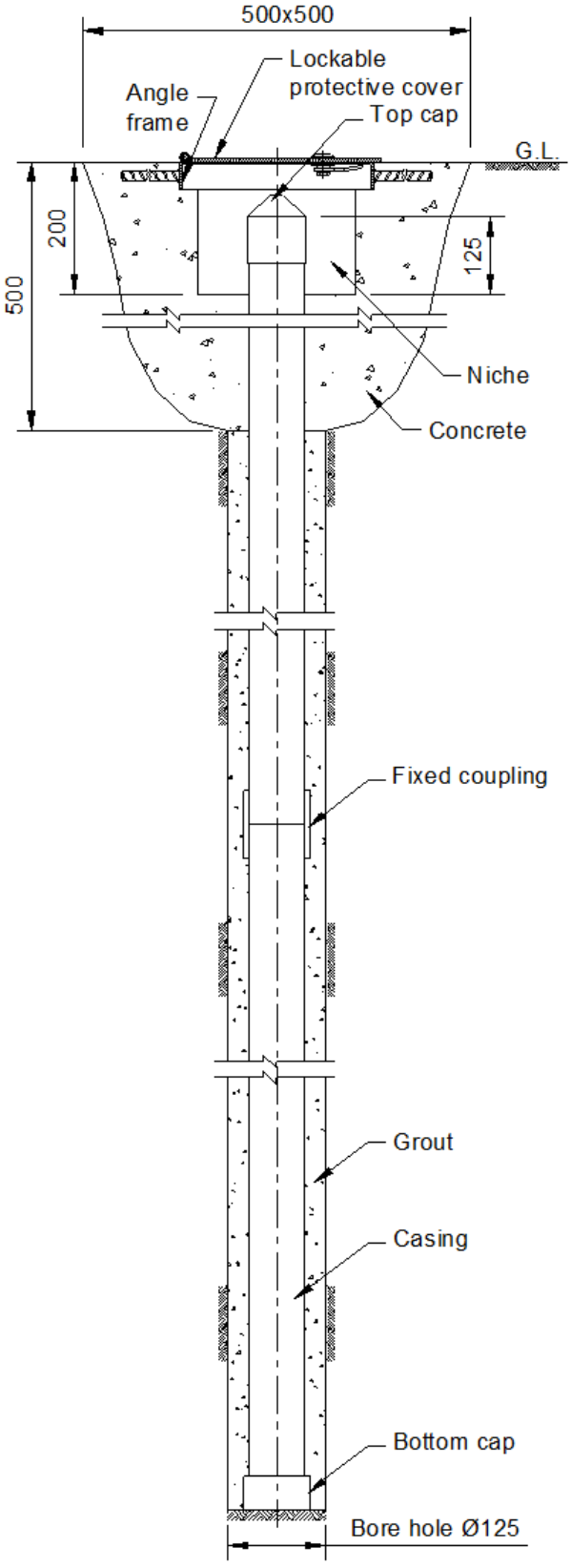


Figure 5.8 checking of casing

e. To counteract buoyancy, if required fill casing with clean water to lower it into guide pipe/borehole.

f. Repeat above procedure for all casings to be installed in borehole.

NOTE: Casing will be buoyant if borehole is water or mud filled and must be filled with water to install it in borehole. When grout is pumped into borehole, water-filled casing becomes buoyant again, because grout is denser than water: To counter this buoyancy, a down force should be applied at bottom of casing by lowering a steel pipe to bottom of casing or suspending a non-retrievable weight from bottom of the casing.

Down force applied at the top of the casing is likely to distort the casing profile. Do not park a drill rig over the casing or apply any other top-down method of counteracting buoyancy.

CAUTION: Do not accidentally drop casing into borehole. During insertion of casing sections, clamps should be used at top of hole to prevent lower casing sections from falling to bottom of hole. For very deep installations, a tension cable may be attached to bottom of casing to relieve tension on upper casing couplings. During process of lowering, casing grooves should be kept aligned to final configuration desired so that later turning of casing is minimized.

CAUTION: When casing reaches correct depth; check proper installation with dummy probe. If probe will not pass or jumps track, pull casing out and rectify problem.

5.2.3 Grouting in borehole

a. Grout casings as directed by project authorities. Ideally, grout should be mixed to match strength and deformation characteristics of material around borehole. In practice, main consideration is to use a grout that allows casing to move with surrounding material. For information, grout mixes used by some authorities are as follows:

Figure 5.9 Casing installation

Hard and medium soils

Cement	50 kg
Bentonite	15 kg
Water	125 litres

28-day compressive strength was about 350 kPa.

Soft soil

Cement	50 kg
Bentonite	20 kg
Water	325 litres

28-day compressive strength was about 30 kPa.

NOTE: Please verify above values yourself in actual conditions before use. Encardio-rite takes no responsibility for correctness of above information at your site as the compressive strength values are dependent upon geology of site and environmental conditions.

b. For mixing grout use a grout mixer or circulation method (figure 5.10), in case a mixer is not available. In the **circulation method,** a rig pump or a trash pump coupled to a gasoline engine (refer to figure 5.10) is used for mixing the grout components i.e. water, cement and bentonite. Subsequently, the same pump can be used for pumping the grout to the bottom of the borehole. It is to be noted that pressure grouting is not required as the grout flows down under gravity.

c. Add cement to water first and mix/circulate. Add bentonite in small quantities slowly during the mixing/circulation process such that lumps of bentonite are not formed. Adjust amount of bentonite to produce a grout within consistency of heavy cream. If grout is too thin, the solids and water will separate. If the grout is too thick, it will be difficult to pump.

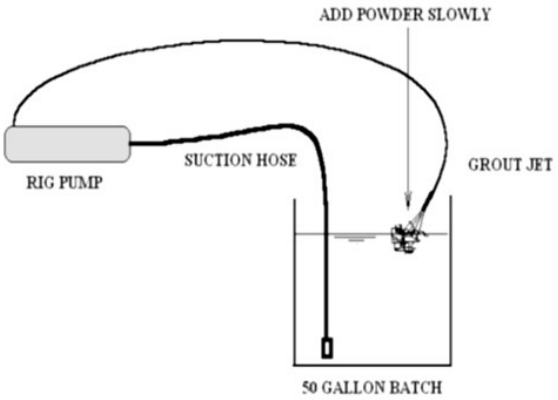


Figure 5.10 Circulation method of pumping grout

d. Pull out and dismantle grout pipes one by one as the hole is being filled with grout.

NOTE: Use a mixer, a grout pump, a pipe or hose for delivering grout. Do not mix grout by hand. Also do not use a water pump to place grout, since pumping grout would damage it.

Properly mixed grout should be free of lumps. It has to be thin enough to pump but thick enough to set in a reasonable length of time. If mixture is too watery, it will shrink excessively, leaving upper portion of the borehole un-grouted. Avoid use of admixtures and grouts that cure at high temperature since these may damage the casing.

The use of hydrated lime rather than cement is sometimes recommended to provide for a more responsive, somewhat weaker backfill.

For plastic casing, heat of hydration of grout or excess grout pressure can deform the plastic. This problem can be eliminated by maintaining casing full of water until grout has set or by grouting hole in stages.

CAUTION: Experience shows that sand or pea gravel should not be used as backfill material unless it is absolutely necessary. These backfill tend to mask movement, not allowing a rigid shear plane to reach the casing.

e. For grouting the inclinometer casing in the borehole use of **tremie method** is recommended (figure 5.11). Lower 20 mm nominal diameter rigid PVC pipe lengths jointed using threaded sockets to around 0.5 m above the bottom of the borehole.

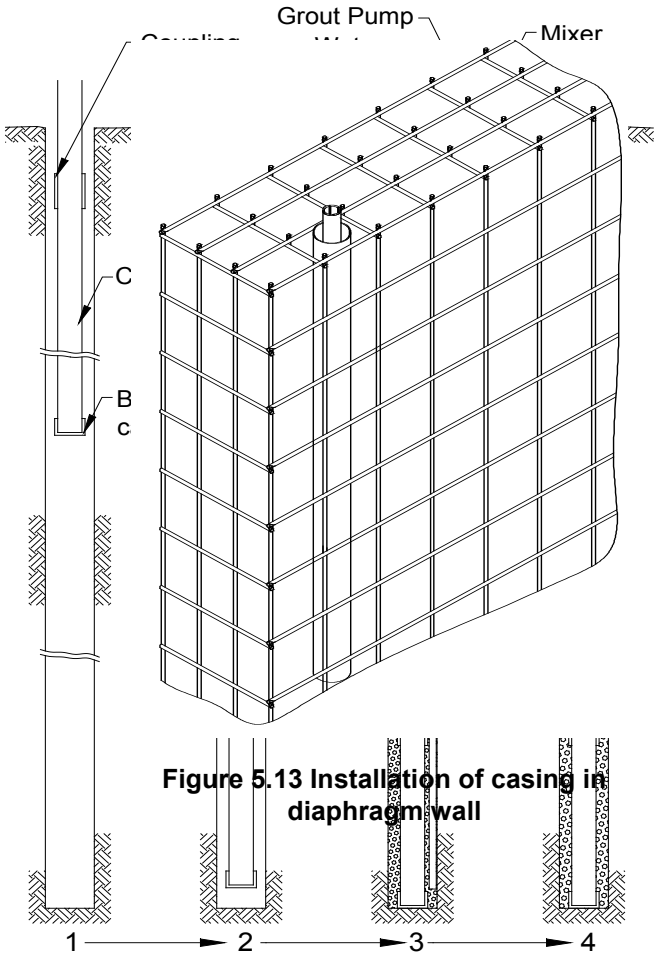


Figure 5.13 Installation of casing in diaphragm wall

NOTE: To overcome buoyancy due to grout which is having a density of 1280 kg per cubic meter, a two stage grouting process should be carried out. In the first stage, bottom 10 m should be grouted and left for at least 12 hours to set. During this stage a clamp has to be installed at the topmost casing of the installation and tied to a firm object to overcome the uplift force of around 14 kg due to the first stage grouting. Rest of the hole to be grouted using tremie method.

Figure 5.11 Grouting by tremie method

NOTE: Pre-grouting is sometimes done in case of a shallow borehole. It is also useful when there is not enough space for the grout pipe in the annulus between the casing and the borehole wall.

f. Flush inside of casing with clean water after grouting to prevent any leaked in grout from sticking to inside of casing and impairing movement of probe.

5.2.4 Top cover

a. Fix protective cover in concrete platform on top of borehole. Protective covers feature a universal key and dust protection for lock (always put back dust protection after locking to avoid lock jamming). Typical dimensions for concrete platform are given in figure 5.8. These may vary depending on local site conditions.

Top of upper most casing should be kept below final ground level and protected by top cap and lockable manhole cover. Cut top of pipe suitably by a hacksaw. Use flat file to make pipe end smooth.

5.2.5 After installation check

a. Check installed access tubing by dummy probe (EAN-26/2.2) for smooth movement upto bottom of borehole.

NOTE: Top of uppermost casing should be 125 mm above base of niche as shown in figure 5.8. The niche is around 200 mm deep. This is necessary for fixing pipe extension jig over casing for taking readings.

b. When not taking readings, gage well should be protected by top cap and manhole cover should be kept locked.

c. Mark tag no. of the installation with paint on inner side of hinged cover.

NOTE: Plying of heavy machinery such as cranes, loaded trucks etc. near protective cover should not be allowed and if required proper fencing with warning flags should be provided. In case it is not possible to avoid movement of heavy machinery over protective cover, specially procure heavy duty covers from factory and embed in a heavy concrete platform.

NOTE: If telescopic coupling is used, settlement sections must be inserted appropriately extended or collapsed. Grease telescopic joint and use mastic and BOPP tape to keep telescopic section at required opening and also to prevent intrusion of grout or backfill materials inside casing.

5.2.6 Marking of grooves (sign convention)

a. Mark casing grooves as 'A+', 'B+' ,'A-' and 'B-' with permanent ink marker pen. If uppermost probe wheel is pointed in direction of major principle plane of movement, casing groove pointing in this direction is marked as 'A+'. Looking down the well, directions 'B+', 'A-' and 'B-' are clockwise from 'A+'.

5.3 Installation in diaphragm wall or pile

5.3.1 Preparation for installation in D-wall – MS casing

Direct installation of inclinometer casing in diaphragm wall or a pile is problematic. It should be avoided. Inclinometer casing will get distorted and stressed when firmly tied to steel structure from bottom to top.

It is also not good to directly expose the casing to heat of hydration and stresses generated during the concreting process. Casing may distort and even get cracked.

a. Fix a 150 mm nominal bore diameter steel guide pipe vertically within reinforced bar cage as shown in figure 5.13. The pipe length to be installed should be worked out in such a way that its top remains around 0.5 m above the existing ground level after cage is fully lowered to bottom of the slurry trench. Bottom of guide pipe should be around 0.5 m above bottom level of cage. It should be sealed at bottom with a concrete plug/plastic cap.

Make sure that jointing of tube lengths is water proof to prevent any grout/concrete from entering into it, while cage is being concreted. Use of dented or distorted pipes shall not be done as this will make installation of inclinometer access tube difficult or even impossible.

Figure 5.14 Installation of MS casing in diaphragm wall cage

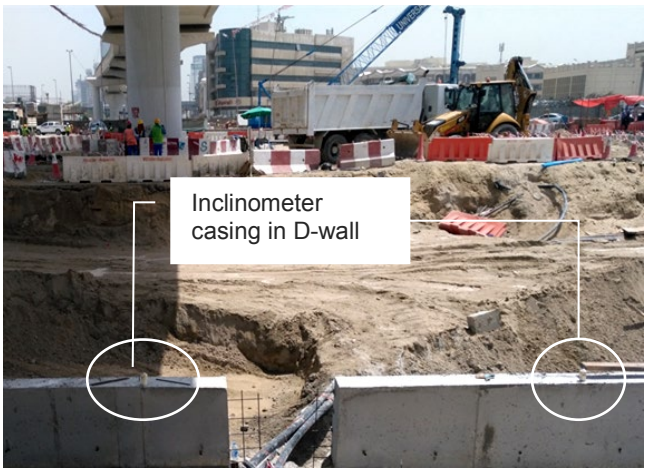


Figure 5.15 Inclinometer casing installed in diaphragm wall

NOTE: It is recommended that an auxiliary guide pipe be installed adjacent to the main guide pipe at 1.25 m approx. centre to centre distance at critical monitoring locations. This auxiliary pipe can be used in case main pipe gets choked and becomes useless due to any reason.

b. Weld guide pipe firmly to cage. Ensure that it remains vertical and is least distorted during lowering of cage.

c. Concrete cage after covering mouth of guide pipe.

d. Flush guide pipe clean with water and verify depth with help of a suitable depth measuring device (e.g. a sounding chain) that it is fully open up to the bottom.

NOTE: Ensure that heat of hydration of mass concrete has dissipated before installing access casing in guide pipe. Use a temperature probe for this purpose. Temperature should not exceed 40^{o}C. The heat of hydration, if present may warp access casing and render installation useless.

5.3.2 Installation of inclinometer casing in MS casing (D-wall)

a. Lower casing with bottom cap into guide pipe gripping it with the safety clamp secured around 500 mm from top.

NOTE: Maintain one pair of casing grooves parallel to the direction in which lateral movement is to be measured i.e. perpendicular to the diaphragm wall.

b. Take a casing pre-assembled with a fixed coupling, having a safety clamp secured around 500 mm from its top end and mate it with the pipe already lowered through the coupling end. Pop-rivet the fixed coupling to lowered casing at four places.

c. Seal joint with mastic waterproof tape and BOPP tape, as described in § 5.1 (c) and 5.1 (d).

d. Remove safety clamp from first casing and lower jointed casings into guide pipe.

NOTE: Always use safety clamp such that casing does not accidentally fall into guide pipe while installing.

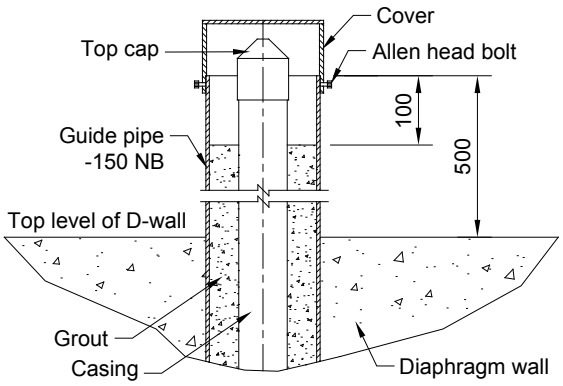


Figure 5.16 protection of casing in diaphragm wall

e. To counteract buoyancy, if required fill casing with clean water to lower it into the guide pipe.

f. Repeat above procedure for all the casings to be installed in the guide pipe.

NOTE: It is preferable to use 20 mm nominal diameter rigid PVC pipe lengths jointed using threaded sockets for grouting. Lower above tubes say up to 0.5 m above bottom of guide pipe.

5.3.3 Grouting in MS casing (D-wall)

a. Prepare a grout mix to be filled in the annular space between the guide pipe and casings as directed by project authorities. If no instructions are available, suggested grout mix is as follows:

Cement	50 kg
Bentonite	10 kg
Water	75 litres

b. It is recommended to flush inside of casing with water after grouting. This is to prevent any leaked in grout from sticking in the casing and impairing the movement of the probe.

5.3.4 Top cover

a. Top of uppermost casing should be 25 mm above top of steel pipe. Cut top of pipe suitably by a hacksaw. Use flat file to make the pipe end smooth.

NOTE: Depth of top of grout face from top of steel casing should be at least 100 mm (125 mm from ABS casing top) as shown in figure 5.16. This is necessary for fixing pipe extension jig over casing for taking readings.

b. Clean exposed portion of casing top and fix top cap.

c. When not taking readings, the gage well should be protected with cover fixed to top of steel casing by four M6 Allen head bolts (figure 5.16).

5.3.5 After installation checks

a. Check installed guide pipe for proper installation before installation of access tubing. Ensure that it is sufficiently vertical and is least distorted.

b. Check installed access tubing by dummy probe (EAN-26/2.2) before lowering inclinometer probe.

c. Ensure fixing protection cover and placing top cap after installation of inclinometer casing.

5.3.6 Marking of grooves (sign convention)

a. Mark tag no. of installation in paint on inner side of steel guide pipe. Also mark casing grooves as

'A+','A-','B+' and 'B-' with permanent ink marker pen. If uppermost probe wheel is pointed in direction of the major principle plane of movement, the casing groove pointing in this direction is marked as 'A+'. Looking down the well, directions 'B+','A-' and 'B-' are clockwise from 'A'.

NOTE: Plying of heavy machinery such as cranes, loaded trucks etc. over the installation should not be allowed and if required proper fencing with warning flags should be provided. If necessary, the guide pipe with inclinometer casing be cut short to just above the diaphragm wall top level and a lockable hinged cover be provided. Readings can be taken using an extension jig.

5.4 Installation in dam embankment (fill) – core section

5.4.1 Precaution for installation in embankment fill (core)

a. In an embankment installation like in a dam, settlement will take place and coupling selected should be long enough to provide for anticipated settlement. Encardio-rite ABS telescopic coupling provides for a displacement of 150 mm.

b. Telescopic type slip joints are usually used only in embankment, but if settlement is anticipated below a dam, they may be used in foundation also.

c. While installation, maintain one groove of inclinometer casing orientated in the direction in which maximum deflection is expected. If the deflection direction cannot be determined, orient north/south.

d. Alignment of grooves (of casing) must be maintained throughout the installation process, to avoid inducing torsion to the casing thereby causing spiral of the grooves.

5.4.2 Protection of installation in embankment fill (core)

a. As the installation progresses in stages over a few months, it is essential that the inclinometer casings be properly protected against damage. The followings precautionary steps are recommended.

- The contractor has to fabricate a circular fencing of G.I. wire with top & bottom end open (2 m dia.) duly flagged, for protection of plastic casing from accidental damage due to nearby construction work. This fencing can be manually raised, as and when the embankment height is raised.
- The exposed top end of the inclinometer casing shall always be kept covered with the help of top cap to prevent any loose soil or rock debris from entering the inclinometer casing.

b. Inclinometer casing in embankment installation can warp from extended exposure to hot sunlight. The exposed part of the inclinometer casing should therefore be properly shielded from sunlight. Suitably cover exposed part of inclinometer casing with tarpaulin or thick black plastic sheet to protect plastic casings from unnecessary exposure to strong sunlight. Ultra violet radiation in sun rays cause faster weathering of the plastic material. Once casings are fully embedded in soil they are safe.

c. A settlement marker should be provided adjacent to top of inclinometer casing that will serve as survey reference point. This will allow inclinometer as well as settlement profile to be referenced to an absolute reference (elevation above sea level) should bottom reference be lost due to any reason.

5.4.3 Installation of casing in embankment fill (core)

a. The first casing to be installed is the one with the bottom cap. Orient casing vertically with help of casing top cap and guy ropes. Use plumb bob for this purpose. Ensure that one groove is oriented in direction of maximum deflection.

b. It is good practice to grout fix lower end of casing. Effort should be made to install casing plumb within 1° from vertical.

c. Remove casing cap and guy ropes as soon as possible because these will have to be re-used as

installation continues.

d. Compact soil carefully around casing and let level rise to around 20 cm below top of casing.

NOTE: An inclinometer installation in embankment requires no special backfill. The soil used for embankment is compacted carefully around the casing.

e. Assemble telescopic coupling using acetone for cleaning and pop rivets, mastic & BOPP tape for jointing suitably extending telescopic coupling to accommodate the expected settlement/rebound as described in § 5.1.2. Grease telescopic joint as a bond breaker for the back fill. Properly seal by mastic and BOPP tape to prevent intrusion of backfill materials inside casing.

f. Assemble next casing to telescopic coupling using procedure described above.

g. Repeat procedure till all casings and telescopic couplings are assembled. This of course will have to go along with the filling of the embankment.

NOTE: In case settlement has also to be monitored, install plate magnets as the required level is reached.

h. Flush inside of casing with water during assembly and after it is fully assembled. This is to prevent any back fill or dirt from sticking on to grooves in casing and impairing movement of probe. Always keep top of casing well plugged with top plug.

5.4.4 Marking of grooves (sign convention)

a. Mark the casing grooves as 'A','B','C' and 'D' with a permanent ink marker pen. If the uppermost torpedo wheel is pointed in the direction of the principal plane of movement, the casing groove pointing in this direction is marked as 'A'. Looking down the well, directions 'C','B' and 'D' are clockwise from 'A'.

5.4.5 Top protection

a. The top of the upper most casing should project around 150 mm above the ground level. Fix the protective top cap and lock it. When not taking readings, the gage well should be protected with the top cap and locked.

5.5 Installation in dam embankment (fill) – crest

5.5.1 Precaution for installation in crest/rockfill section

a. Procedure for installation of casing in core and crest is different as crest area principally consists of rock aggregates varying in size. This type of rock fill may show considerable lateral shift with large localized variation along the depth. Localized lateral movement in rock fill is often beyond allowed deformation limits of standard inclinometer casings causing casings to either shear off or crush.

b. Surrounding inclinometer casings with graded fine sand or clay up to some distance may not help as it has been observed that due to piping effect, fine fill material can easily drain off through voids in surrounding large rock aggregate fill matrix. Loss of fill material around inclinometer casings may give rise to cavities that cause rock pieces from surrounding rock fill matrix to come loose and strike inclinometer casing causing catastrophic damage to the casings.

5.5.2 Protection of installation in crest/rockfill section

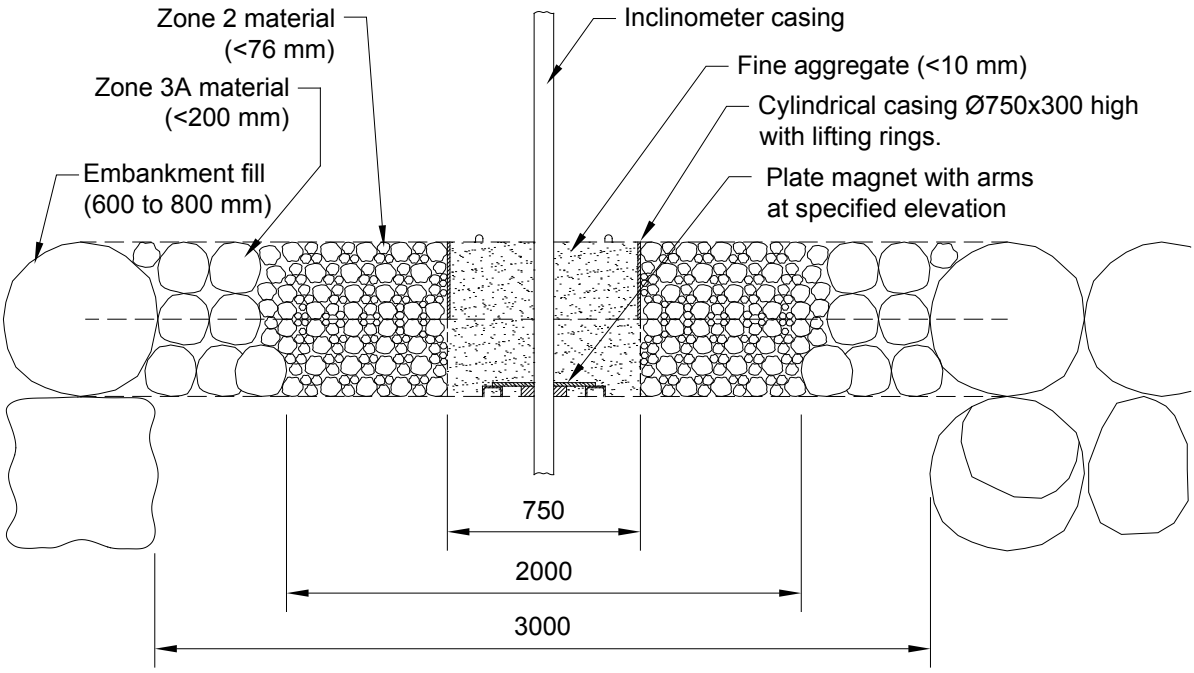
Same as mentioned in section 5.4.2 above (protection of installation in embankment fill-core).

5.5.3 Installation of casing in crest/rockfill section

a. Before installation the location of the inclinometer casing (northing & easting) should be properly marked by surveying.

b. Generally following installation instructions in § 5.4 wherever applicable, it is best to surround the

inclinometer casing in crest with graded material as per procedure described below. A typical installation is illustrated in figure 5.17.



All dimensions are in mm.

Figure 5.17 Typical details of fill around

c. Because of graded fill requirement around inclinometer casings, the installation will have to proceed after every 1.2 metres of main fill is in place and compacted. A pit of approximately 3 metres diameter at the bottom shall be left during the fill procedure.

d. Place a mild steel cylinder (typically 750 mm diameter x 300 mm high) formwork centred on the inclinometer location mark. Locate bottom cap of casing at the location mark and centre the cylinder around the casing.

e. Stand the bottom casing vertically on the capped end with the help of guy ropes to be held by three persons each.

f. Orient casing vertically with help of guy ropes. Use plumb bob for this purpose. It is good practice to grout fix lower end of casing. Effort should be made to install casing within 1º from the vertical.

g. Carry on fill operation in lifts of approximately 300 mm height. Build next layer only when preceding layer has been properly compacted. Only use hand held compactors for compaction around casings (figure 5.18). Four fill layers will raise fill height by around 1.2 m that is just sufficient to hold the inclinometer tubing vertically in place.

h. The sheet steel cylinder is used to place and compact the sand and fine aggregate fill immediately around the inclinometer casing. After the layer is compacted the cylinder is raised up and out of the finished layer in preparation for the next layer. The other two graded zones shown in the figure 5.17 outside the 750 mm diameter cylinder can be carefully hand placed and compacted. It is easier if the outer layer of fill material is placed first followed by the inner layer of fill material.

i. Remove guy ropes only after casing is two-thirds embedded in fill.

j. Once fill level reaches top of casing, add another length of casing using a telescopic coupling.

k. Suitably extended telescopic coupling to accommodate expected settlement/rebound. Hold casing in extended condition with help of two pop rivets riveted diametrically opposite telescopic joints. Grease the telescopic joint or cover with plastic as a bond breaker for the back fill. Waterproof sealing tape is used to extend and keep the telescopic section to the required opening. Proper sealing by the waterproof tape is also necessary to prevent intrusion of backfill materials inside the casing.

l. Repeat above steps till all the plastic casings and telescopic couplings are assembled. This of course will have to go along with the filling of the embankment. Insure that joints are riveted and waterproof sealing tape is properly applied.

CAUTION: Groove alignment must be maintained throughout the installation process, to avoid inducing torsion in the casing thereby causing spiralling of the grooves.

m. Flush the inside of the casing with water during assembly and after it is fully assembled. This is to prevent any back fill or dirt from sticking on to the grooves in the casing and impairing the movement of the probe. Always keep the top end of the casing covered with the top cap.

5.5.4 Marking of grooves (sign convention)

Mark the casing grooves as 'A','B','C' and 'D' with a permanent ink marker pen. If the uppermost torpedo wheel is pointed in the direction of the principal plane of movement, the casing groove pointing in this direction is marked as 'A'. Looking down the well, directions 'C','B' and 'D' are clockwise from 'A'.

5.5.5 Top protection

The top of the upper most casing should project around 150 mm above the ground level. Fix the protective

Figure 5.18 Casing with telescopic coupling being installed in rockfill section of dam, using hand help compactor

Figure 5.19 Casing with telescopic coupling installed in rockfill section of dam, supported by guy ropes.

top cap and lock it. When not taking readings, the gage well should be protected with the top cap and locked.

NOTE: A settlement marker should be provided adjacent to top of inclinometer casing that will serve as survey reference point. This will allow inclinometer as well as settlement profile to be referenced to an absolute reference (elevation above sea level) should bottom reference be lost due to any reason.

6 PREPARATION FOR AND OBTAINING READINGS

For detailed instructions, refer to EAN-26 Digital inclinometer system operation manual # WI 6002.103.

6.1 Sign convention

The inclinometer readout uses a sign convention for casing orientation. Follow sign convention strictly. Mark casing groove orientation with a permanent ink marker pen on outside of casing and inside of lockable cover.

Mark 'A+' in direction in which maximum deflection is expected. Looking down the well, mark other grooves clockwise as 'B+', 'A-' and 'B-'. While inserting probe into casing, the uppermost probe wheel near connector should be pointed in direction of major principle plane of movement i.e. in direction marked A+. (In some dataloggers, direction is marked as A, B, C and D). Refer to figure 6.1.

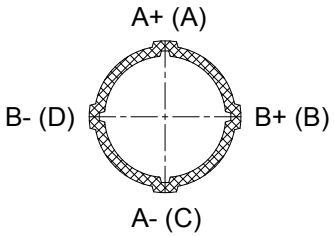


Figure 6.1

6.2 Determine as-built elevation using prism target

a. Determine initial Northing (X) and Easting (Y) positions of casing top by surveying after the casing is set. For this purpose use a prism assembly with holder pin (to be ordered separately) for inclinometer casing EAN-AT-70 with ERT-10P2 prism target. Readings should be taken with an accurate and precise total station. This data should be treated as a reference during verification of deflection at a later date.

b. Determine the elevation of the pipe top using a digital level with precise levelling method.

6.3 Connecting probe to cable reel

a. Open lock on protective cover and remove top cap from casing.

b. Take out probe from transport case. Remove protective cap from top of probe. You will find an Ó' ring on face of probe. Inspect condition of "O" ring. Replace if damaged or permanently flattened.

c. Carefully push connector part of connector assembly at end of cable on to inclinometer probe connector after ensuring that keying slots and splines of probe and cable connectors are properly aligned (otherwise

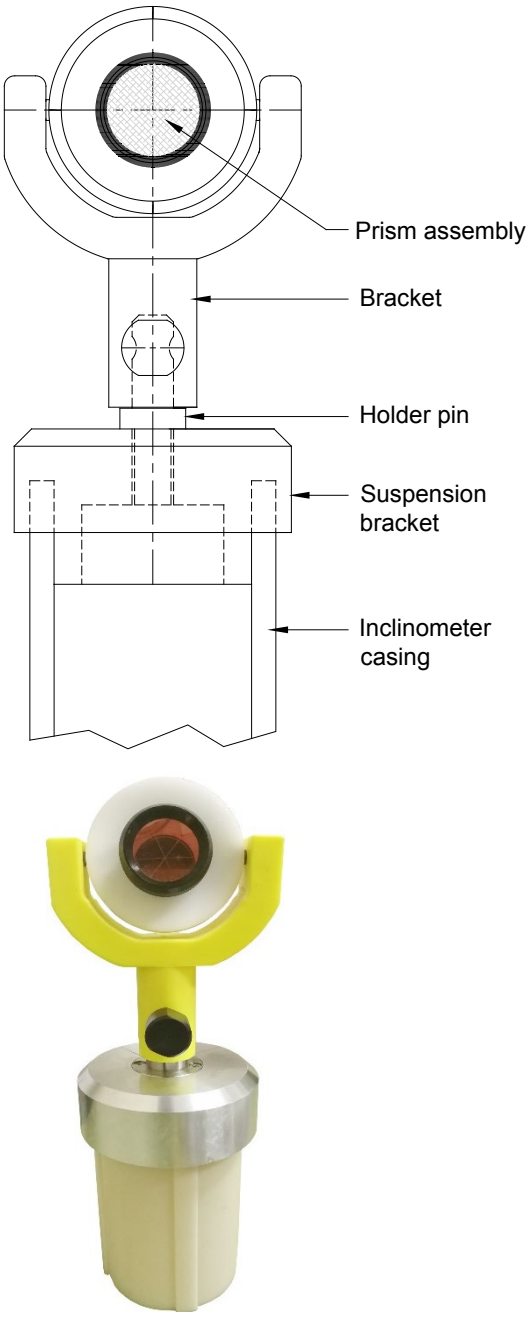


Figure 6.2 Prism adapter for inclinometer casing

the connector assembly will not fit).

d. Do not apply unnecessary force. Screw on (not forcibly) with supplied spanner the threaded retaining shell of cable connector assembly to inclinometer probe to make a water tight connection.

6.4 Taking readings

NOTE: Reference '§' numbers given below are from EAN-26 digital inclinometer system operation manual # WI 6002.103.

NOTE: Depth to bottom of casing should already be known so that probe can be eased on to bottom without jolting it or damaging it.

a. Section 4 "Readout Unit" of Digital Inclinometer System Operation Manual # WI 6002.103 describes the procedure for setting up a bore hole and logging the borehole. Follow the instructions given the operation manual to log the borehole.

b. When the logging is complete remove the cable grip from the access tubing and take out the inclinometer probe.

c. Disassemble cable from probe. Wipe clean the probe and replace protective caps on the cable and the probe. Oil the wheel, springs and axle pivots with the supplied oil (or any other locally available light duty machine oil).

d. Rewind cable onto cable reel, clean it and fix the connectors in place.

e. Replace the top plug on the casing and lock it. In case any additional protection is provided, install it.

NOTE: Not properly cleaning probe, associated cable, connectors and datalogger after use is the most frequent cause of failure of the inclinometer system. Not oiling the wheel, springs and axle pivots will invariably result in costly repairs and equipment downtime.

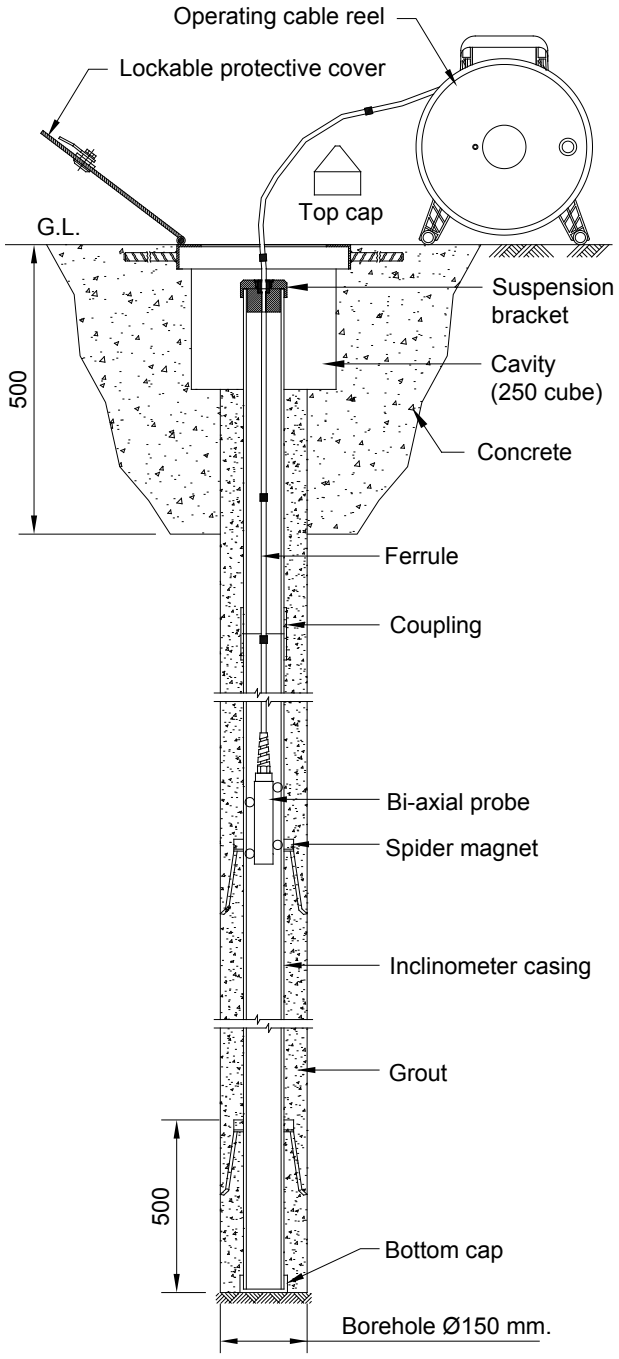


Figure 6.3 Taking readings

6.5 Guidelines for correct readings

Do's

If large deformations are expected to take place, use dummy probe to check condition of gage well before lowering the actual probe.

Check if directions 'A+', 'B+', 'A-' and 'B-' are clearly marked on casing top. In case the marks are fading away, re-mark them.

Always allow enough time for the accelerometers (inside the probe) to "settle down" before taking any reading.

When raising probe during a set of readings, take extreme care in duplicating depths A+ and the A- reading runs such that errors contributed by casing irregularities are minimized.

Replace the discharged cable reel battery with a fully charged battery if battery voltage goes below 6 V. The inclinometer system is supplied with two Lithium batteries for the reel unit.

Keep all electrical connections clean - use alcohol or a spray cleaner suitable for electronics that will not damage the outer cable covering or panel finish.

Replace probe wheels and axles if they become wobbly or sticky.

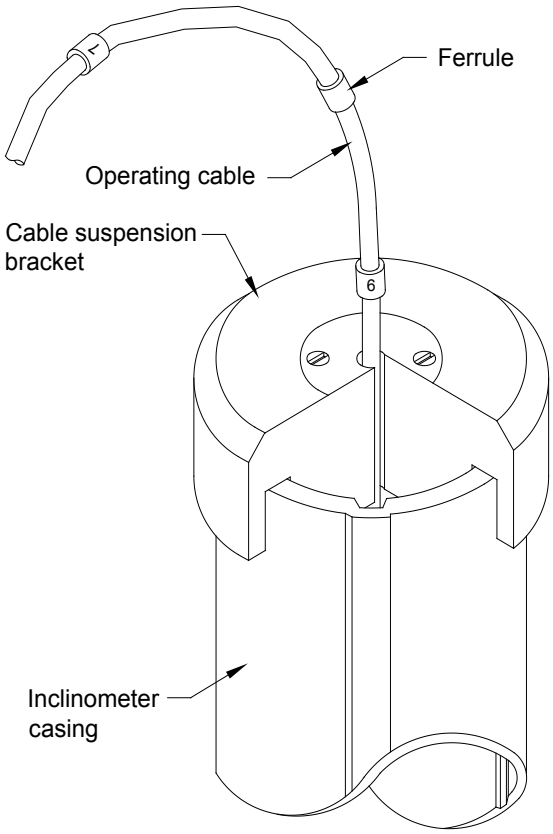


Figure 6.3

Constantly check conditions of "O" ring on probe face to maintain a watertight seal.

Keep protective plugs in place on all electric outlets to prevent physical damage or liquids spilling into them.

Do not's:

Hard bumps to probe can misalign and/or break the accelerometers or break internal electrical connections.

Hard bumps to indicator can dislodge internal batteries, break electrical connections, shift LCD readouts or rupture the watertight case seals.

Bending connecting cable over sharp objects or walking on it can sever internal conductors or puncture the outer waterproof coating.

NOTE: The inclinometer system is like other delicate equipment and its use requires common sense and reasonable care!