Guideline for Installation of Slope Inclinometer (SI)

1. GENERAL

A slope inclinometer (SI) is a device for monitoring subsurface movement. Slope inclinometers are often used to monitor the performance of slopes and embankments. They can provide early warning of developing instabilities; allow the assessment of pattern, depth and rate of movement; and help engineers make better and more timingly decisions on possible remedial actions to such sloping movements. Other applications include monitoring the impact of excavations on surrounding facilities, deformation of structures, and settlement of embankment fills and roadway subgrades.

These guidelines provide the minimum standard of care for installation of pneumatic piezometers on Alberta Transportation projects. Deviations from these guidelines may be permitted by the Director of Geotechnical and Materials Section, Technical Standards Branch.

These guidelines do not address: the selection of slope inclinometer materials; the rationale for locating and placing SIs; the frequency of monitoring; or other aspects of a properly executed instrumentation monitoring program. It is expected that the staff or consultant responsible for the installation will chose the correct type of SIs. The depth and location of placement of slope inclinometers will be determined by site conditions, soil conditions, objectives of the monitoring program and other factors.

2. INSTALLATION

Inclinometer casing is typically installed in a borehole, but it may also be embedded in a fill, cast into concrete, or attached to a structure. The guidelines for each of these installation types are discussed below.

2.1 Installation of vertical applications

- The borehole diameter should be large enough to accommodate the inclinometer casing and a tremie pipe so that grout can be pumped into the annulus from the bottom up. Alternatively, the SI casing diameter should be chosen based on the expected drilling method.
- Once the hole has been drilled to the required depth, the first length of casing shall be inserted, complete with bottom cap and attached tremie pipe. Additional lengths of casing are added until the desired depth is reached, which does not necessarily have to be to the bottom of the hole. Depending

on the coupling system used, tape may be considered to further seal the joints between lengths of SI casing as an additional barrier to ingress of grout and water. This also keeps fine grained soils from getting around shear wires or threads and allows for easier disassembly of the casing if needed.

- Once the SI casing is lowered into the hole to the required depth, a pair of grooves should be aligned in the expected direction of ground movement. This should be done only if it can be accomplished without applying excessive torque to the casing.
- Grout should be pumped through the tremie pipe into the hole, displacing any groundwater within the borehole. The grout may be a mixture of bentonite, Portland cement, and water in which the proportions of each are chosen such that the grout is able to “set-up”, thereby bonding the SI to the surrounding soils. Grouts with a thick consistency are favoured considering they more significantly displace groundwater within the borehole, are stronger when cured, set-up quicker, and are less susceptible to flowing away from the borehole through permeable layers. It is up to the installer to choose an appropriate grout formulation and to apply it in a way that results in a satisfactory installation taking into account the equipment available. It is intended that after installation is complete, the casing should accurately reflect any displacement of the surrounding ground. For best performance in soft ground, the stiffness of the grout should be reasonably matched to that of the surrounding ground.
- During casing installation, groundwater, drilling fluid, or fluid grout within the borehole may exert an uplift buoyancy force on the casing, lifting the casing out of the borehole. It is recognized that most installations involve some degree of restraint on the top of the casing to counteract these uplift forces, however it should avoid applying too much force at the top of the casing as this tends to result in snaking of the casing or kinked or separated joints. In this context, use of a 25 kg weight on top of the casing is considered acceptable. Where significant buoyancy forces are expected during installation and grout, the following possible measures may be used:
  A. Anchor the casing at the bottom of the borehole prior to grouting by special accessory “casing anchors”.
  B. Fill the casing with water. But beware of filling the casing too early in a dry hole, as this may blow off the bottom cap.
  C. Lower a steel pipe to the bottom of the casing and gently rest it on the bottom cap. Care must be taken not to break off the cap.
  D. Grout the borehole in stages. This can be very helpful even if the first stage is just a few meters long.
- Inclinometer casing should be normally installed to a depth of 3 to 6 m below any expected displacement. This part of the casing should be embedded in soil that is not undergoing movement to act as a baseline for the above moving soils, as well as a check on the performance of the measurement system. On those rare occasions when stable ground does not exist within a reasonable depth, the casing top shall be surveyed each time the instrument

is read. The results may then be plotted from the top down, taking the movement of the casing top into account.

- Where there are no special constraints, a casing should stick up about 0.5 to 0.75 m.
- Spiral twisting of the grooves should not exceed 0.75 degrees per metre length of the tubing. Because the grooves in modern casing are formed by broaching rather than extrusion, there is little risk of excessive spiral. Where necessary (e.g., on very deep installations, typically >60m) a spiral survey of the casing grooves should be carried out after installation and an appropriate correction applied by the data reduction software.
- Upon completion of the installation, the inside of the casing should be kept clean so that the probe can travel accurately in the grooves all the way in and out of the casing. If the grooves become contaminated by grout, they should be cleaned by flushing with water and gentle brushing, and a dummy probe can be lowered to the bottom to check that the grooves are clear. Due to the need to keep the SI casing as clean as possible, it is never recommended to perforate the casing to make the casing also function as an observation well. Further, if the casing is filled with clean water to overcome buoyancy problems during installation, the water level within the casing should be reduced such that it is not susceptible to seasonal freezing.
- After installation and curing of the grout, two sets of inclinometer readings should be taken to provide a reliable baseline. If the two sets show any apparent movement, a third set should be taken.

2.2 Installation of horizontal applications

- The casing should be installed in a horizontal sand-filled trench or horizontally inclined borehole, with either one or both ends open to surface. If the casing is closed at the far end, a dead-end pulley and cable-return pipe section should be installed at that end.
- An initial survey should be carried out to establish the actual shape (or absolute position) of the casing, and subsequent surveys should be able to reveal changes in the profile if subsurface movement has occurred. The daylight end of the casing may need to be surveyed at each reading to verify if movement is occurring at that end.
- The casing should be inclined about 3% towards the open end to allow water drainage from the hole.

2.3 Installation of structural applications

- Inclinometer casing should be attached or embedded in structures.
- For any installations, an ABS casing should be installed within a steel casing (also called construction casing) first, while the steel casing is integrated/tied to rebar reinforcement cage. The construction casing should be able to resist

harsh handling and impacts during construction that could damage the inclinometer casing if it was installed directly in the structure.

- Alternatively, the ABS casing may be tied directly to the rebar reinforcement, or installed into core holes within the structure if monitoring is required after construction is complete.

Common guidelines:

- Considering the quality of SI installation strongly influences the accuracy of resulting data and its ease of interpretation. To return the best possible data, the casing should ideally be straight and well supported by stable grout (or fill in horizontal installations) over its full length. In a vertical installation, this means that the casing should be as vertical as possible and centred in the borehole.
- To achieve a vertical installation, a “vertical” hole needs to be drilled, making it important to take care in choosing level drill pads where possible, and to limit the use of excessive rig down-pressure when hard layers or obstructions are encountered. Further, the SI casing to be installed in the hole should be as straight as possible, making it important to store the casing in a safe place prior to installation and ensuring that it is supported evenly to avoid warping or bending. On site, casing should be protected to avoid warping due to prolonged exposure to the heat of direct sunlight.
- In some site locations, especially for short-term use, an exposed casing at surface with an end cap is acceptable. However, for most locations, a locking steel enclosure (casing protector) or a monument case should be used.
- It is suggested that the annular space between the SI casing and the casing protector not be grouted, in order to reduce casing damage due to frost-jacking. When the cap of the casing protector is removed, the SI casing should protrude at least 3 inches above the lip of the casing protector. This is required in order to allow for the addition of a cable clamp and/or pulley used by some systems (e.g., deep installation) during reading.
- If the top of the SI casing must be lower than the lip of the casing protector, 6-inch clearance should be provided around the casing in order for the pulley assembly to be attached directly to the casing.
- For installations on paved road surface, a metal flush-mount monument and cover should be used.
- For horizontal inclinometer system, manholes or pits may be constructed on one or both ends to access and protect the system. In horizontal application, deposits are easily accumulated along the lower groove so that cleaning by hosing water or gentle brushing is needed as required.
- On active or future construction sites, bollards, barriers, or barricades can be used to create a buffer distance from each installation to protect from impact by construction traffic.

- All instruments should be clearly and permanently labelled with their reference number.

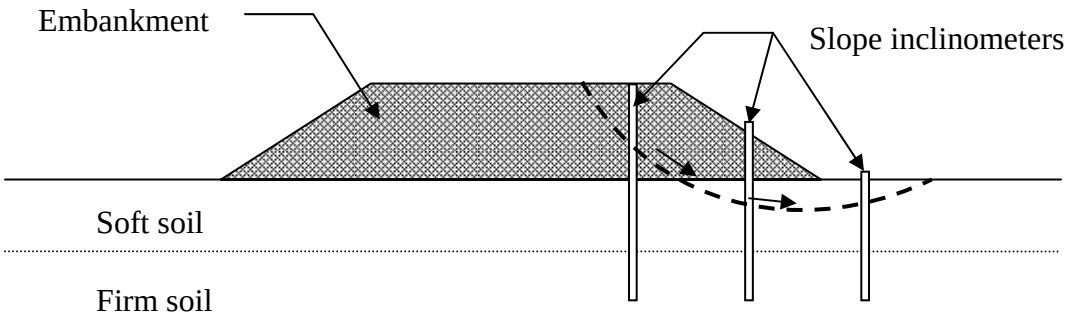

Figure 1 Typical installation of slope inclinometer – vertical applications

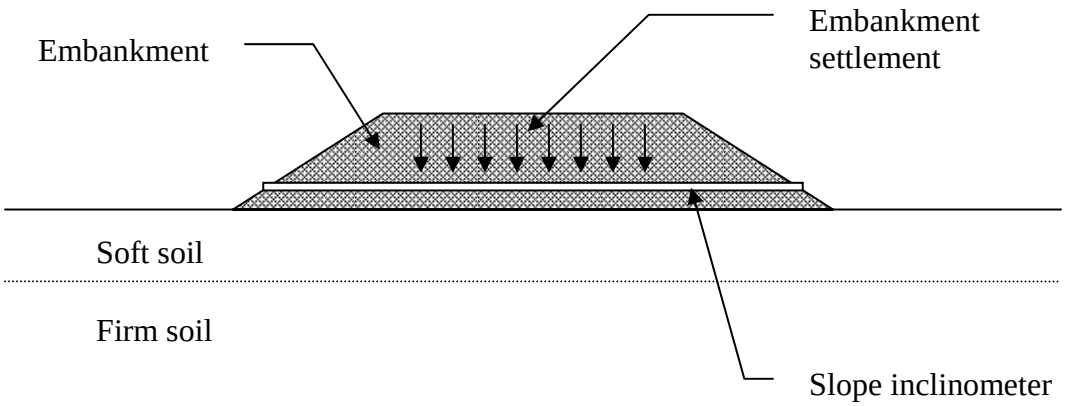

Figure 2 Typical installation of slope inclinometer – horizontal applications

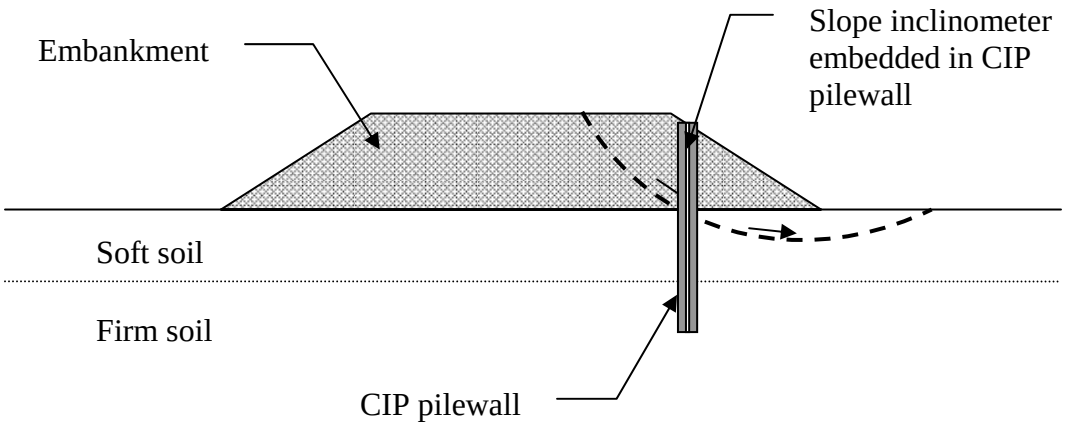

Figure 3 Typical installation of slope inclinometer – structural applications