Rigid Rod Multi-Point Borehole Extensometer
Installation and User Manual

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RST Instruments LTD.
11545 Kingston St.,
Maple Ridge, BC
Canada V2X 0Z5
SALES + SERVICE +MANUFACTURING
604-540-1100 | info@rstinstruments.com
Toll Free (USA & Canada) 1-800-665-5599
www.rstinstruments.com

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

LIST OF EQUATIONS

REVISION HISTORY

Rev.	Revision History	Date	Prepared By	Approved By
A	Initial release	19 November 2024	TW, SM	JP, SP, CA

1 Intended Audience

This guide is for the personnel responsible for installing or using an RST Rigid Rod Multi-Point Borehole Extensometer (MPBX).

This manual provides the installation steps for different orientations and types of anchors available. Instructions for measuring and interpreting MPBX readings are also provided.

2 Safety Precautions

⚠	Normal safety precautions should be followed, and proper personal protective equipment (PPE) should be worn when working in the field, including safety glasses and nitrile gloves.

3 Icons and Conventions Used In This Guide

This guide uses the following icons to call attention to important information.

🛑	**WARNING:** This icon appears when an operating procedure or practice, if not correctly followed, could result in personal injury or loss of life.
⚠	**CAUTION**: This icon appears when an operating procedure or practice, if not strictly observed, could result in damage to or destruction of equipment.
→	**NOTE**: This icon appears to highlight specific non-safety related information.

4 ABBREVIATIONS AND ACRONYMS

This section lists abbreviations and acronyms used in the document.

Abbreviation or acronym	Definition
PPE	Personal Protective Equipment
ID	Inside Diameter
OD	Outside Diameter
SS	Stainless Steel
MPBX	Multi-Point Borehole Extensometer
HOSS	Heavy Over-hole Suspension System
PSI	Pound Per Square Inch
mPa	millipascal
PVC	Polyvinyl Chloride
ABS	Acrylonitrile Butadiene Styrene
HDPE	High Density Polyethylene
SPT	Standard Penetration Test

6 INTRODUCTION

RST's Multi-Point Borehole Extensometers (MPBX) are used to determine the stability and movement of soil, rock, and concrete structures. A Borehole Extensometer with multiple anchor points can be used to determine movements between set anchor points within a single borehole.

MPBX are usually installed within a borehole using a grout backfill which provides the bond connection between the extensometer's anchor point ends and the borehole walls. Typical installations only have a single instrument cable exiting from the borehole collar, connected to a remote data logger or a readout unit.

A typical rod Extensometer consists of a reference head, usually installed at the collar of a borehole, and one or more in-hole anchors, each of which is fixed in place at a known depth in the borehole. As the soil or rock shifts, the spaces between nearby anchors inside the borehole change, as well as the spaces between each anchor and the reference head. This allows for an accurate determination of distribution, magnitude, rate, and acceleration of deformation in the rock or soil mass intersected by the borehole.

NOTE: The number of anchors and anchor depths should be selected based on site geology, area's structural geometry, and other location-specific details.

The use of two or more anchors at various depths allows the engineer to differentiate potentially dangerous deep-seated movements from more trivial surface spalling.

MPBX uses vibrating wire displacement transducers as measurement sensors for stable and accurate outputs which can be temperature corrected.

RST produces both Rigid Rod and Flexible Rod MPBX. The type of MPBX employed depends on the application and installation requirements.

Rigid Rod Extensometers are shipped in individual components (rods, anchors, head) for assembly at the project site as the equipment is installed in the ground. Rigid rods can monitor either extension or compression but usually require more aerial room at site if working with 3 m rod lengths. Typically, rods have an O.D. of 6.4 mm (¼ in).

NOTE: Refer to Figure 1 for a dimensional overview of the MPBX head and collar assembly. Both product photography and diagram are provided.

Figure 2 shows the Rigid Rod MPBX assembly, along with an individual stainless-steel rigid rod, shown with a PVC sheath and groutable anchor.

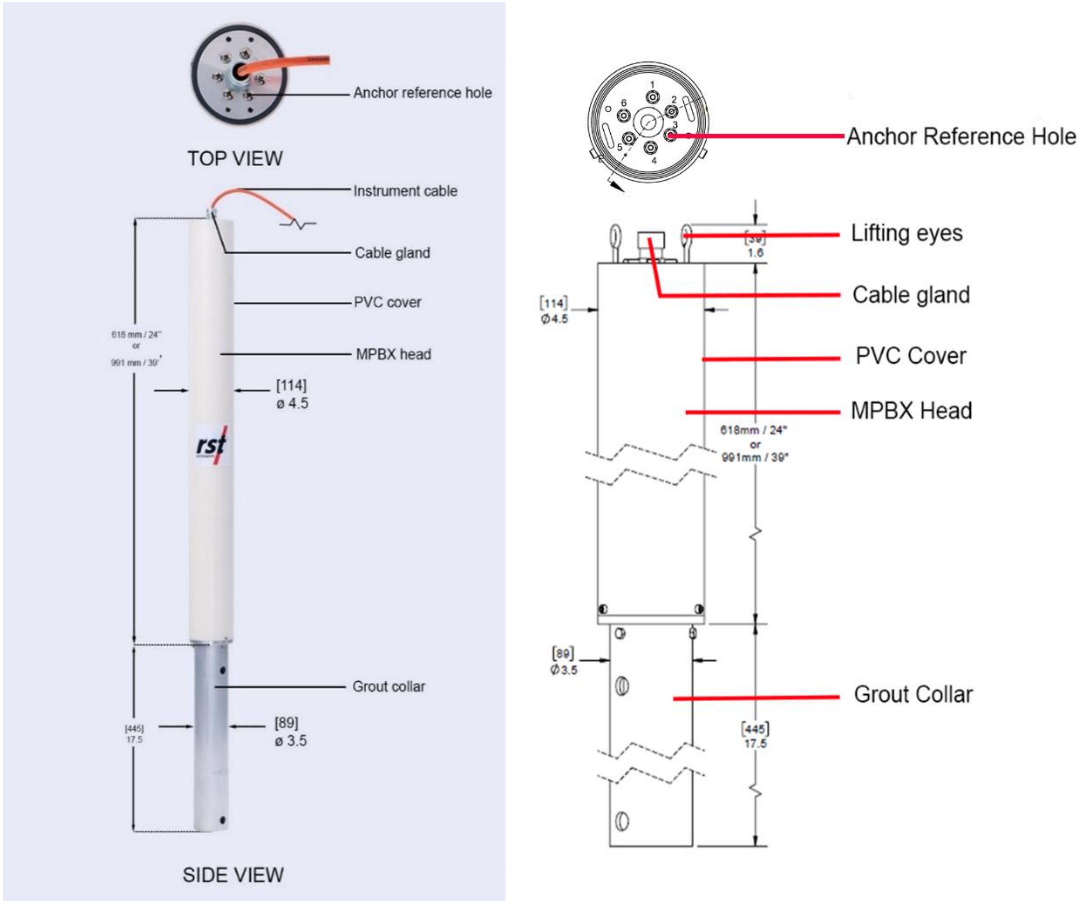

Figure 1: MPBX and Collar Dimensional Overview

Figure 2: Rigid Rod MPBX and Individual SS Rigid Rod with PVC Sheath and Groutable Anchor

The stainless-steel rigid rods (1/4”) are the most common and applicable. These come flush coupled with individual sheaths and are resistant to corrosion over time. They can also be used with all anchor types.

6.1 FEATURES

- High accuracy and reliability
- Adjustable anchor lengths in field
- Easily adaptable to remote readout unit
- Rugged construction for operation in challenging environments
- Simple installation and operation

6.2 APPLICATIONS

- Ground movement around tunnels
- Deformation of dam abutments and foundations
- Ground movement behind retaining walls, sheet piling, slurry walls, etc.
- Ground movements in the walls of open pit mines
- Deformation of concrete piles (tell-tales)
- Deformation in the walls and roofs of underground openings
- Subsidence above tunnels and mine openings
- Settlement and heave of foundations due to loading

6.3 DIFFERENT MPBX CONFIGURATIONS

NOTE: Please refer to the relevant section based on the installation type needed for the application.

CAUTION: Vise Grip® pliers have a spring-loaded locking mechanism within the handle. An unintended blow or knock to the handle may release the Vise Grip® pliers, which would cause the Extensometer assembly to either fall in to or out of the borehole.

It is therefore recommended that PVC electrical tape be used to secure the Vise Grip® plier handles whenever the Extensometer installation is being held at rest at the borehole collar.

A lanyard can also be attached to the Vise Grip® pliers and secured to a mounted item so it does not fall down the borehole during installation.

Vise Grip® pliers are usually used when assembling new lengths and for the tremie connections.

6.3.1 Downward Installation

NOTE: This is the most straightforward installation orientation as the Extensometer assembly rests on the borehole's invert level and can easily be lowered into the borehole.

CAUTION: Ensure that the system does not fall down the borehole.

Use a pair of Vise Grip® pliers to hold the Extensometer rods or tremie pipe while building and lowering the assembly into the borehole.

For a downward-directed borehole, rest the Vise Grip® pliers on the top edge of drill casing or grout collar.

Use of safety cable and HOSS (Heavy Over-hole Suspension System) is recommended, especially for installation within deep boreholes as this reduces the exertion required to lower and lift instruments into boreholes.

NOTE: Downward-directed borehole which are inclined will require slightly different procedures than the regular downhole installation.

The inclined system requires the use of rigid rods and/or tremie pipes to push the system down the borehole due to friction with the borehole wall.

6.3.2 Upward Installation

CAUTION: Ensure that the system does not fall down the borehole and out of the borehole collar.

Upward-directed boreholes require different grouting procedures and techniques than downward-directed boreholes, as grout will tend to flow out of the borehole due to gravity. Rigid rods and/or tremie pipes will be used to push the system up the borehole.

Use the Vise Grip® pliers to hold the Extensometer rod while building and pushing the rod assembly up into the borehole.

Ensure the Vise Grip® pliers are suspended from a secure anchor point located adjacent to the grout collar. This is usually done with an anchor bolted into the surrounding rock and a steel cable or rope sling arrangement.

NOTE: Upward-directed borehole which are inclined will require slightly different procedures than the regular upward installation.

The inclined system requires the use of rigid rods and/or tremie pipes to push the system up the borehole due to gravity and friction with the borehole wall.

Additional MPBX accessories and special equipment may be required for grouting an inclined upward borehole.

Contact site engineer/consultant and/or RST's support for technical issues or further instructions.

6.4 MPBX HEAD INSTALLATION ABOVE GRADE OR BELOW GRADE

RST MPBX can be installed with the Extensometer head exposed above the borehole’s surface (above grade) or with the Extensometer head buried below the borehole’s surface (below grade).

6.4.1 Above Grade Head Installation

The MPBX is installed with the Extensometer head exposed above the borehole’s surface.

This is advantageous as the MPBX head is serviceable, and the installation is easier as the user is not required to work below the borehole surface or in a manhole with tight working space.

A disadvantage is that the exposed MPBX head may interfere with surface traffic, construction equipment, or the public. The exposed extensometer head could also result in vandalism and/or damage due to debris from the surroundings or nearby construction.

6.4.2 Below Grade Head Installation

The MPBX is installed with the Extensometer head buried below the borehole’s surface or with only a small portion of the head sticking out of the borehole’s surface.

This is advantageous as the MPBX head will not obstruct surface traffic or construction equipment. It is also protected from possible vandalism or damage due to debris.

A disadvantage is that the MPBX head is not serviceable unless a manhole is constructed to house the Extensometer head. The user will have to work in an awkward position below the borehole surface and/or with a tight working space inside the manhole.

6.5 TYPES OF MPBX ANCHORS

4 common types of anchors for RST's MPBX system are:

6.5.1 Groutable Anchor

Groutable anchors are simple to install and the preferred anchor for downward directed holes.

Groutable anchors are unaffected by blasting activities.

NOTE: Groutable anchors are not suitable for use in soft ground or soil as the grout column may inhibit performance.

They can be used in upward directed boreholes with a special grouting technique. Contact RST Instruments for more information.

Figure 3: Groutable Anchors

6.5.2 Groutable Anchor with Spring Legs

Spring-type groutable anchors are recommended for use in boreholes in soft rock or consolidated soil where the grouted rebar anchor may not be able to provide a secure attachment to the borehole wall.

The mechanically activated spring legs provide extra contact with the borehole wall to ensure that anchor slippage will not occur.

Figure 4 shows the configuration of the three-spring leg anchor arrangement, which when deployed (Figure 5), will attach to the borehole wall at six points.

NOTE: Backfill grouting must still be carried out when spring leg anchors are used. This ensures that the anchors are securely attached to the adjacent borehole walls. In addition, backfill grouting fixes the Extensometer sheaths and rods in the hole so that lateral movements, which result in reading inaccuracies, cannot occur. Backfill grouting also ensures that downhole caving or deterioration will not affect the Extensometer's long-term operation.

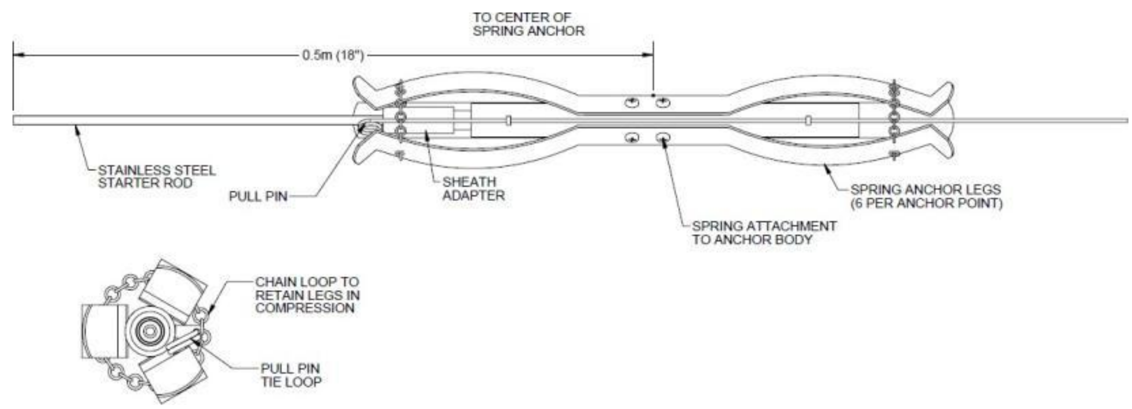

Figure 4: Spring-Type Groutable Anchor General Arrangement

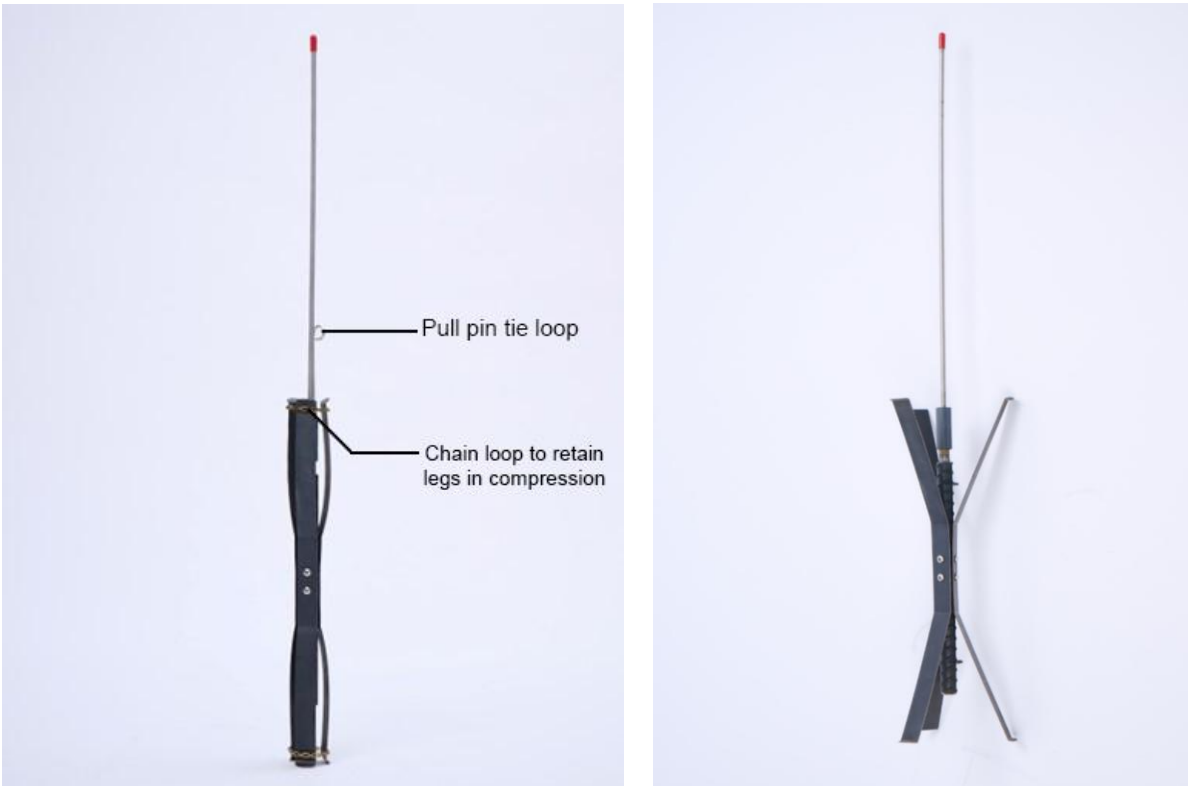

Figure 5: Spring-Type Groutable Anchor with Legs Closed (Left) and Deployed (Right)

6.5.3 Hydraulic Borros Anchor

Hydraulic borros anchors are recommended for use in soft ground and soil where deep penetration of the prongs is required for good anchorage, especially where hole squeezing is anticipated.

NOTE: Borehole squeezing occurs when the soil adjacent to the borehole moves inward, toward the hole, reducing the borehole diameter. Soft soil consisting of clay or silts (soil with SPT N-value less than 5) is especially prone to squeezing.

Standard Penetration Test (SPT) is a common in-situ test to determine the relative density of soils and the approximate shear strength parameters.

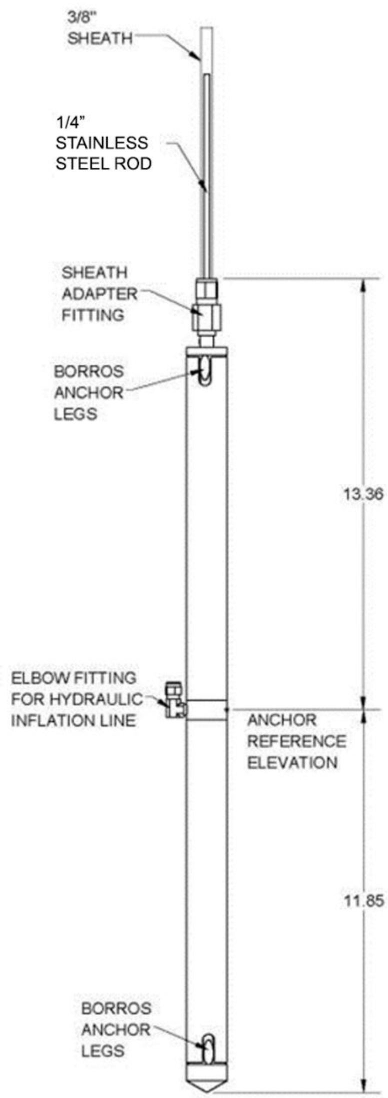

Figure 6: Borros Type Anchor General Arrangement

→ **NOTE**: A borehole that uses hydraulic borros anchors can also be grouted for additional bonding.

Figure 7: Borros Type Anchor Overview

Figure 8: Borros Type Anchor Elbow Fitting with Hydraulic Inflation Line Attached

6.5.4 Bladder Type Hydraulic Anchor

Bladder-type hydraulic anchors (see Figure 9) are generally used in boreholes with fractured rock or dense soil where grouting is difficult. These anchors use friction to attach to the borehole wall.

These anchors consist of a pressure-tight, copper tube wrapped around a reel of high tensile strength plastic. Attached to the copper bladder is a high-pressure nylon inflation line and check valve. The inflation of the anchors is done with a hydraulic pump which causes the copper bladder to expand and “unwind,” filling the space between the spool and the borehole wall. The copper permanently deforms so that the shape does not change, and the grip is not lost even if the check valve fails. The hydraulic bladder type anchors can accommodate up to 30 mm of oversize without loss of grip.

NOTE: Bladder type anchors are custom made with specific dimensions according to installation requirements and borehole considerations. Contact RST for more information.

Figure 9: Bladder-Type Hydraulic Anchor

7 INSTALLATION OF RIGID ROD MPBX

7.1 REQUIRED TOOLS AND COMPONENTS

The following tools and materials are required or recommended for the installation of the Extensometer system:

- Grout tube / tremie pipe
- Measuring tape
- Hex Allen Key set (Imperial)
- Wrench set (Imperial) – specifically, ½" and 9/16"
- Philips screwdriver (Phillips and flathead)
- Thread locker (Loctite #242 or equivalent)
- PVC electrical tape – ¾" rolls, multiple
- PVC solvent
- PVC cement

7.2 SUPPLEMENTARY TOOLS AND COMPONENTS

- Safety cable

NOTE: RST recommends using 3/32" 7x7 braided stainless steel safety cable for deep borehole systems.

- Hydraulic pump (for hydraulic anchors)
- Hydraulic oil (for hydraulic anchors)
- Tubing and tubing fittings (for hydraulic anchors)
- For deep borehole systems: RST's Heavy Over-hole Suspension System (HOSS)
- Vent tube for upward installations
- Grease for O-rings and moving parts
- Wire marker tape
- Marking pens
- Fast set cement for upward directed boreholes
- Spare parts (O-rings, set screws, bolts & screws)

7.3 INSTALLATION GUIDELINES

Rods may be sheathed in individual PVC protective pipe (nominal ¼ in. ID) to minimize frictional effects between different rods and between rods and the borehole wall. Protective pipes may also be filled with oil if the borehole is inclined downward to lubricate the rods and further minimize frictional effects. When placing the rods into the borehole, ensure proper orientation.

NOTE: For more information about the kind of oil to be used, please contact RST.

NOTE: These installation instructions are general and may require alteration to suit specific site conditions and the required configuration of the instrument.

Please consult and seek appropriate approval from site engineer / consultant for final installation procedures.

For additional installation support and troubleshooting help, please contact the support team at RST Instruments.

CAUTION: Electrical sensors should be verified before installation to ensure they have not been damaged during shipment or handling on site.

7.4 SENSOR FUNCTION TEST

CAUTION: Care must be taken to protect the instrument cable from damage.

1. Connect the MPBX cable to a readout unit according to the wiring code in Table 1.

2. Confirm the reading matches the appropriate "B" value as per the provided calibration record at its current sensor stroke setup.

7.5 BOREHOLE PREPARATIONS

→ **NOTE**: Ensure that the borehole is drilled to the appropriate depth, so that the anchor and tremie pipe assembly rests on the bottom of the borehole and is not freely hanging.

It is recommended that the depth of the borehole is 1m deeper than the deepest anchor elevation (see Figure 10).

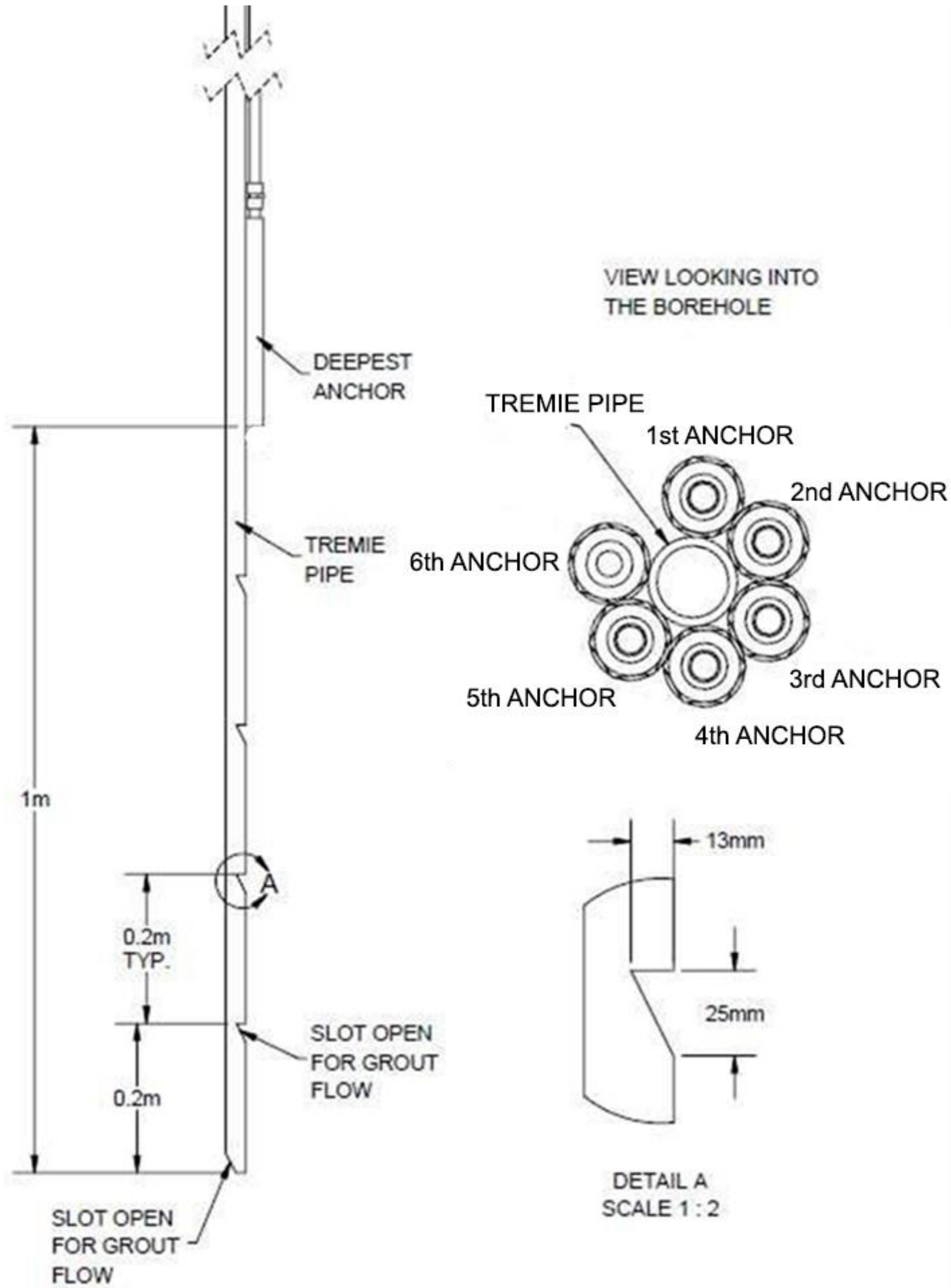

Figure 10: Recommended Borehole Depth Illustrated

7.5.1 Grout Delivery Tube (Tremie Pipe)

RST recommends using a semi-rigid delivery line to successfully navigate irregularities in the borehole wall. ¾” Class 200 PVC plastic tremie pipe works well, but other semi-rigid pipe/tube products made from ABS or Polyethylene plastics may also be acceptable with a slightly modified installation method.

The tubing ID should be between 12 and 25 mm to ensure low line friction and proper grout delivery.

NOTE: For assistance with downward directed borehole, a weight can be attached to the bottom of the delivery grout tube.

For upward directed borehole, a more rigid grout delivery line is required.

CAUTION: Steel products should not be used for downhole grout delivery lines due to the tensile strength of the steel which could act as a reinforcement in the grout backfill and impact the function of the installed instrument Anchors.

CAUTION: It is necessary to resolve water-loss problems prior to the Extensometer installation.

NOTE: Ensure that the required backfill grouting can be effectively carried out in the borehole.

It is recommended that downhole water pressure testing is performed prior to instrument installation.

If water loss problems are encountered during water testing, either:

- Pressure-grout the hole and re-drill to establish an acceptable lower permeability.
  OR
- Abandon the leaky hole in favor of a new hole without permeability issues.

7.6 RIGID ROD INSTALLATION PREPARATIONS

1. Compile a reference table containing the calculated lengths between each anchor, starting from:
    - The deepest anchor (for downward boreholes)
      OR
    - The uppermost anchor (for upward boreholes), close to the borehole collar

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NOTE: This reference table will determine the length of Extensometer rods and PVC sheaths to be installed before adding the next anchor.

For example, if each anchor was spaced 10 m apart, then 10 m worth of Extensometer rods and PVC sheaths would be installed onto the first anchor, before proceeding with the installation of the second anchor.

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2. Organize the Extensometer rods and PVC sheaths into anchor groups, starting with the deepest (for downward boreholes) or uppermost (for upward boreholes) anchor.

3. Verify that all lengths of Extensometer rod and PVC sheaths are present for each anchor to reach its target depth.

NOTE: The use of a long table or sawhorses is recommended to ensure that all the instrumentation segments can be laid out and clearly organized prior to the installation.

SS rods and PVC sheaths are typically provided in 1 m, 2 m, and 3 m lengths, as required for the installation.

Ensure that both ends of stainless-steel rods and PVC sheaths are free from dirt, debris, or damage as this will affect the connection between the pieces.

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4. Using a Sharpie ® felt marker, number each stainless-steel rod at both ends sequentially in the order of installation.

NOTE: RST recommends using letters to designate which Extensometer the stainless-steel rod belongs to and a number designating the rod location (from the bottom upwards).

For example: the first rod threaded to the deepest anchor extension would be labelled “A1” at both ends. The subsequent rod would be labeled “A2” at both ends, and so on. The second anchors’ rods would be labeled “B1”, “B2”, and so on.

7.7 MPBX WITH RIGID ROD INSTALLATION

NOTE: For the purposes of clarity, the instructions provided in this section are for downward-oriented boreholes which will have a grout delivery line (tremie pipe) installed at the bottom of the hole and a vent line or opening installed at the hole collar.

Upward-directed boreholes are the opposite; with grout delivery occurring at the borehole collar and venting occurring through a vent line installed at the borehole's bottom (higher in elevation than the borehole collar).

7.7.1 Installation with Groutable Anchors

NOTE: The first section of the anchor consists of the rebar and the starter rod.

The center point of the re-bar length is the Extensometer anchor point for technical purposes.

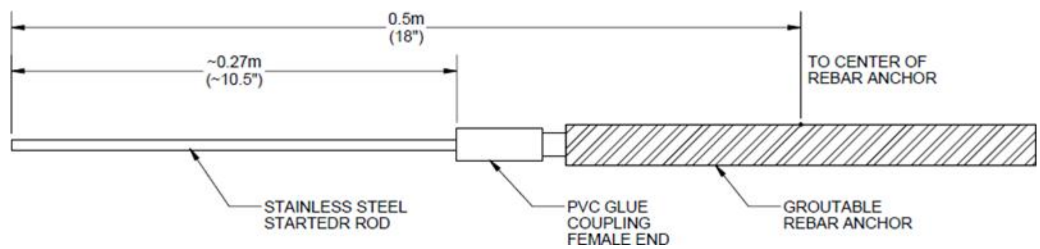


Figure 11: Groutable-Type Anchor General Arrangement

1. Cut a few angled slots (approximately 25 mm (1 in.) in length, see Figure 12), 0.2 m (8 in.) apart from each other, starting approximately 0.2 m (8 in.) from the bottom of the grout delivery line (tremie pipe).

NOTE: The angled slots allow grout to flow out into the borehole in case the bottom of the delivery line is blocked.

2. Place the first groutable anchor beside the tremie pipe, approximately 1m from the bottom of the tremie pipe (see Figure 12).

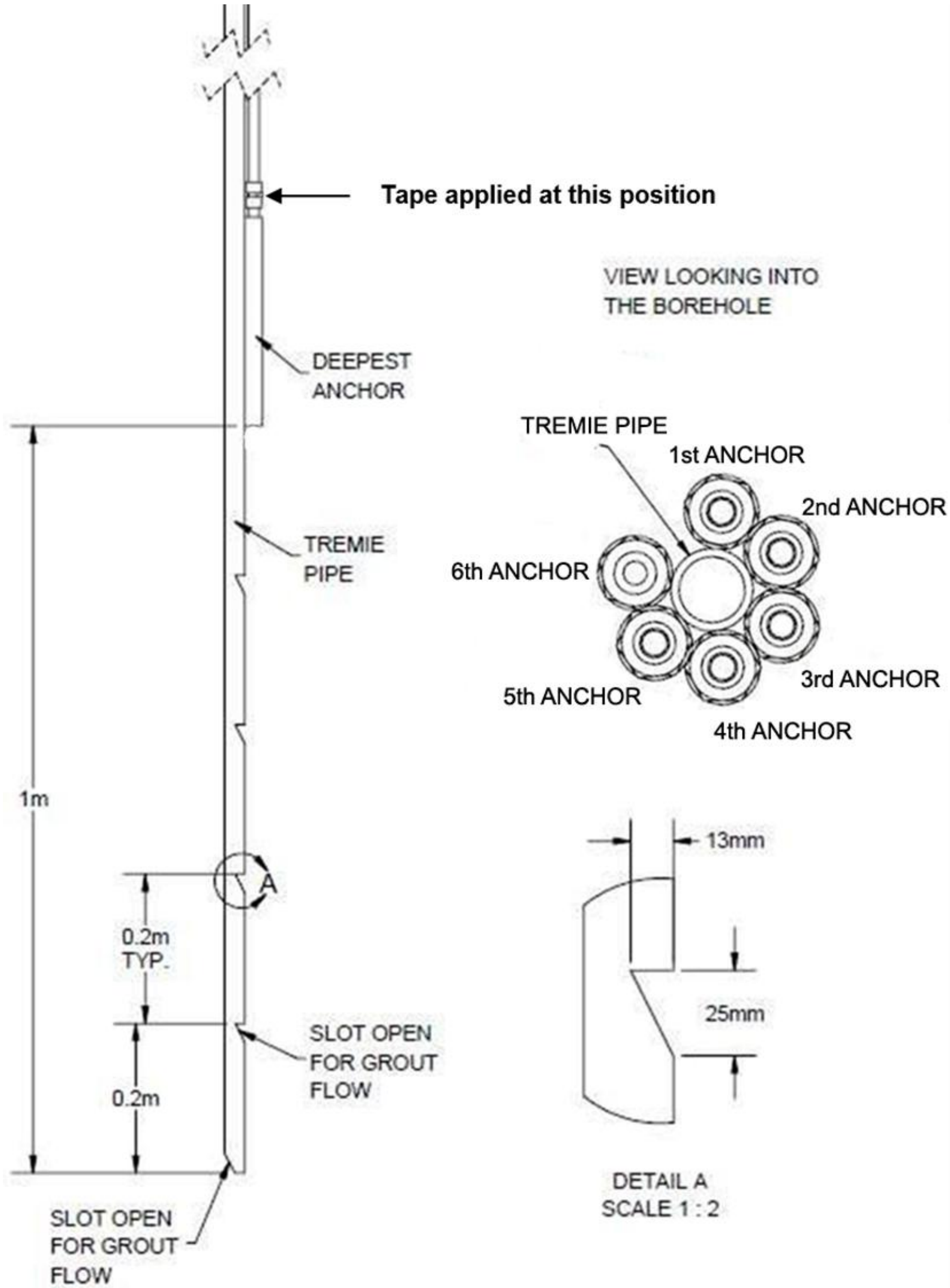


Figure 12: Slotted Openings on Tremie Pipe and Anchor Orientation

NOTE: It is recommended that the borehole is drilled such that the bottom of the tremie pipe rests on with the bottom of the drilled borehole to manage the assembly weight. Otherwise, the assembly must be held suspended over the borehole until the grout sets, which is more difficult in practice.

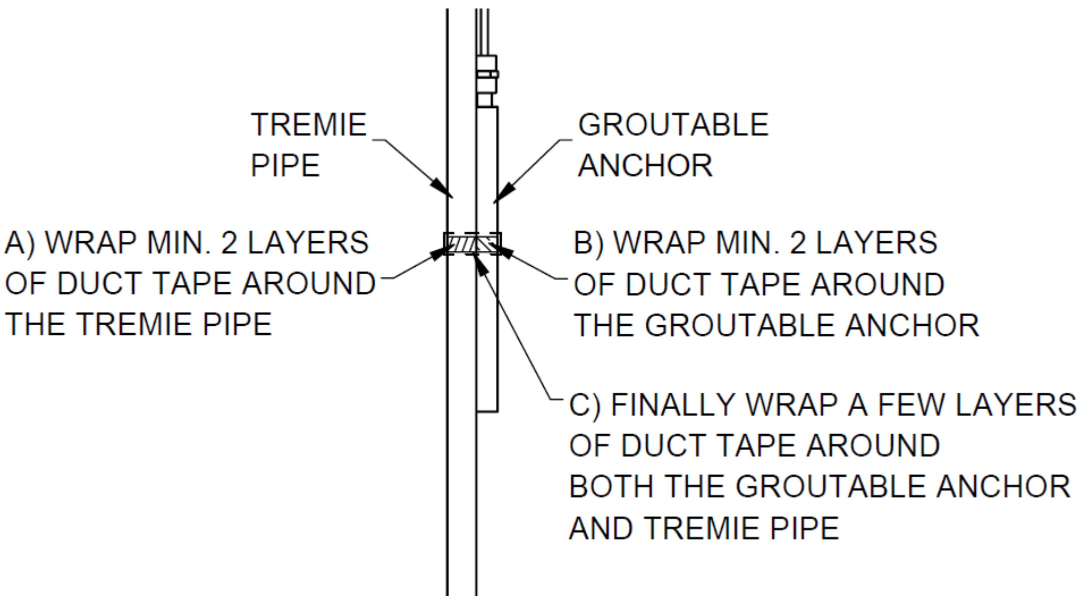
3. Tie a safety wire rope to a slot towards the lower end of the tremie pipe (excepting the last slot) to aid the lowering of the anchor and rod assembly into the borehole (see Figure 12).

4. Tape the groutable anchor to the tremie pipe to bundle them together.

NOTE: To maximize the bonding strength and minimize the chances of the groutable anchor slipping off, the following is recommended (see image below):

i. Individually cover the tremie pipe with two wrappings of duct tape, ensuring that the slots are not covered by duct tape, as this may interfere with the flow of grout
ii. Individually cover the groutable anchor with two wrappings of duct tape
iii. Finally, cover the tremie pipe and groutable anchor together using another two wrappings of duct tape

Please ensure that there is no tape on the groutable section of the anchor as that would limit the bonding strength of the grout to the anchor. Apply the tape just above the groutable section of the anchor, leaving the rebar texture fully exposed.



5. Add the next section of SS Extensometer Rods to the anchor and rod assembly, as per the plan from Section 7.6: Rigid Rod Installation Preparations.

NOTE: Apply a drop of Loctite © 242 to the male screw threads at the bottom end of the SS Extensometer rod before threading it to the rod assembly.

Check the reference labeling on each Extensometer rod to confirm that the correct rod has been selected for installation.

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6. Add the next section of PVC sheaths to the anchor and rod assembly, as per the plan from Section 7.6: Rigid Rod Installation Preparations.

7. Clean both ends of the PVC sheath with PVC solvent cleaner (male and female ends). Slide the newly cleaned PVC sheath length (female end first) over the SS Extensometer rod. Apply a liberal coating of PVC cement to the outer diameter of the clean PVC sheath and insert it into the PVC coupling from the assembly, rotating slightly during insertion.

→ **NOTE**: Alternatively, wrap a few layers of electrical tape around the PVC pipe joint if applying PVC cement is not feasible.

A disadvantage of this alternative is that the strength between PVC joints will be greatly reduced. In this case, the PVC sheath must not be used to hold the entire weight of the anchor and rod assembly.

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8. Apply a few wraps of duct tape or electrical tape around the PVC sheath with the tremie pipe every 3 meters to maintain orientation and prevent twisting.

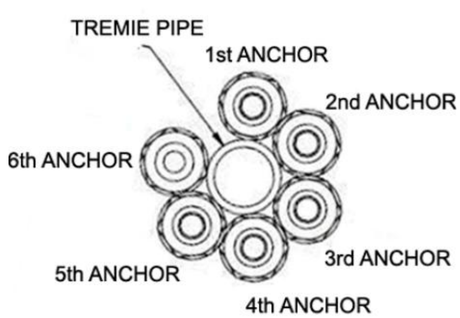
9. Lower the assembly into the borehole using the tremie pipe to take the load. Release the safety wire rope slowly to prevent the assembly from accidentally dropping into the borehole.

10. Repeat Steps 5 to 9 as required, to add additional extensometer rods and PVC sheaths to the assembly until the point where the next groutable anchor is required to be added, as per the plan in Section 7.6.

11. Place the next groutable anchor segment at a tangent to the tremie pipe, at approximately 60 degrees clockwise (looking into the borehole), from the previous groutable anchor and rod assembly. Adjust into the correct relative depth position, as per the plan from Section 7.6.

→ **NOTE**: The next anchor needs to be added such that it is arranged in clockwise order, when looking down the borehole collar.

This clockwise arrangement will match the clockwise order of the number stampings on top of the Extensometer head.



12. Tape the Groutable Anchor to the tremie pipe to bundle them together.

NOTE: To maximize the bonding strength and minimize the chances of the groutable anchor slipping off, the following is recommended:

i. Individually wrap the tremie pipe with two layers of duct tape
ii. Individually wrap the groutable anchor with two layers of duct tape
iii. Finally, wrap the tremie pipe and groutable anchor together using another two layers of duct tape

13. Add the next section of SS Extensometer rods to the anchor and rod assemblies.

NOTE: Apply a drop of Loctite © 242 to the male screw threads at the bottom end of the SS Extensometer rod before threading it to the rod assembly.

Check the reference labeling on each Extensometer rod to confirm that the correct rod has been selected for installation.

14. Add the next section of PVC sheaths to the anchor and rod assembly, as per the plan from Section 7.6: Rigid Rod Installation Preparations.

15. Clean both ends of the PVC sheath with PVC solvent cleaner (male and female ends). Slide the newly cleaned PVC sheath length (female end first) over the SS Extensometer rod. Apply a liberal coating of PVC cement to the outer diameter of the clean PVC sheath and insert it into the PVC coupling from the assembly, rotating slightly during insertion.

NOTE: Alternatively, wrap a few layers of electrical tape around the PVC pipe joint if applying PVC cement is not feasible.

A disadvantage of this alternative is that the strength between PVC joints will be greatly reduced. In this case, the PVC sheath must not be used to hold the entire weight of the anchor and rod assembly.

16. Wrap a few layers of electrical tape at several points (approximately 2m apart) around the PVC sheaths and the tremie pipe, always maintain clockwise arrangement.

CAUTION: **Do not allow the PVC sheaths to cross over.**

17. Lower the assembly into the borehole using the tremie pipe to take the load. Release the safety wire rope slowly to prevent the assembly from accidentally dropping into the borehole.

18. Repeat Steps 13 to 17 as required, to add additional extensometer rods and PVC sheaths to the assembly until the point where the next groutable anchor is required to be added, as per the plan in Section 7.6.

19. Rest the assembly at the bottom of the borehole, with the tremie pipe reaching the bottom of the borehole while all anchors are maintained at their correct elevations.
If the assembly is not resting at the bottom of the borehole, the entire weight of the assembly needs to be suspended from the borehole collar, using the safety wire rope and/or the tremie pipe.

20. Add additional extensometer rods and sheaths to the assembly to ensure the rod for each anchor point protrudes from the borehole collar at the same height as the extensometer head.

NOTE: Rod protrusion length:

- 30 inches (≈ 76 cm) for 50 mm/100 mm sensor range for the Extensometer head
- 45 inches (≈ 114 cm) for 150 mm/200 mm sensor range for the Extensometer head

21. Refer to Appendix A for instructions on grouting the borehole.

7.7.2 Installation with Groutable Anchors with Spring Legs

CAUTION: Great care must be taken to ensure that the pull lines to the trigger pins of the spring anchors are not accidentally pulled and activated during the installation.

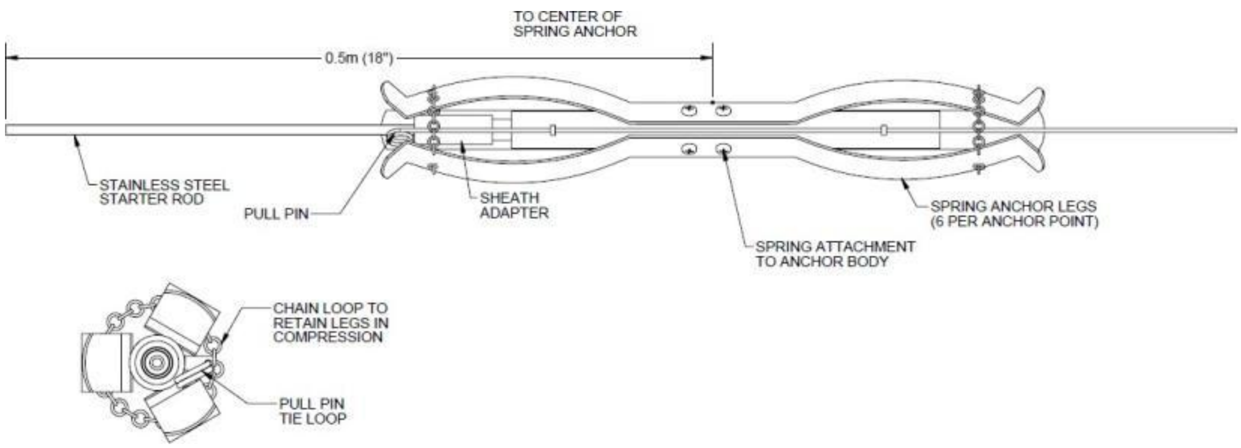
An accidental activation would immobilize the installation within the borehole, mid-task. Movement in either direction would be impossible and there would be no corrective action available that would not severely damage the installation.

For this reason, Groutable Anchor with Spring Legs should only be used when there are no other options available.

NOTE: Installation instructions for groutable anchors with spring legs are very similar to groutable anchor installation instructions.

Refer to Section 7.7.1: Installation with Groutable Anchor for detailed instructions on how to attach the anchor to the tremie pipe and add Extensometer rods and PVC sheaths to the assembly.

CAUTION: Keep a firm hold on the Extensometer during this process. Do NOT release the anchor and rod assembly, even when all the anchors have been deployed.



1. Attach a safety wire rope to the hook at the bottom of the groutable anchor to help lower the anchor and rod assembly into the borehole.

2. Wrap the groutable anchors via their middle to the central tremie pipe using duct tape.
3. Attach a pull line or braided steel cable to the hook on the trigger pin for each anchor.

4. Leave a little slack in the pull lines near the trigger pins. Using 2 strips of electrical tape, attach the lines securely to the PVC sheathing to avoid accidental activation.

CAUTION: Do NOT tape the trigger pin to the PVC sheathing or tremie pipe as it could prevent the spring legs being activated.

NOTE: Pull lines should be well-marked, as to which anchor they belong to, so that the anchor deployment can be done in sequence from the lowest anchor to the topmost anchor.

This helps prevent unequal strain from occurring in the extensometer rods and PVC sheaths between the anchor locations.

5. Lower the assembly into the borehole section-by-section until all anchors are in their respective elevations, as per the plan from Section 7.6.

6. When the entire Extensometer assembly is in position and all anchors are ready to be deployed, pull the pull line or braided steel cables to activate the spring leg on each anchor, starting from the lowest anchor to the topmost anchor.

7. Once all the anchors are deployed, refer to Appendix A for instructions on grouting the borehole.

7.7.3 Installation with Borros Anchors

NOTE: The installation of borros anchors requires the use of a hydraulic pump. Ensure the hydraulic pump is in working condition and all safety precautions are in place prior to using the tool.

NOTE: When several anchors are employed in one borehole, ensure correct rod alignment, and prevent weaving of the measurement rods.

Installation instructions for borros anchor with spring leg are very similar to groutable anchor installation instructions.

Refer to Section 7.7.1: Installation with Groutable Anchor for detailed instructions on how to attach the anchor to the tremie pipe and add Extensometer rods and PVC sheaths to the assembly.

CAUTION: Great care must be taken to ensure that the inflation line is not punctured or damaged during the installation. A damaged inflation line will result in the borros anchor not being activated.

1. Attach a safety wire rope to the hook at the bottom of the borros anchor to aid lowering the anchor and rod assembly into the borehole.

2. Wrap the Borros Anchors by the portion just below their central fitting to the tremie pipe using duct tape (See Figure 13).

   The anchor should be secured to the tremie pipe so that prongs being extended will not be hindered (see image below).

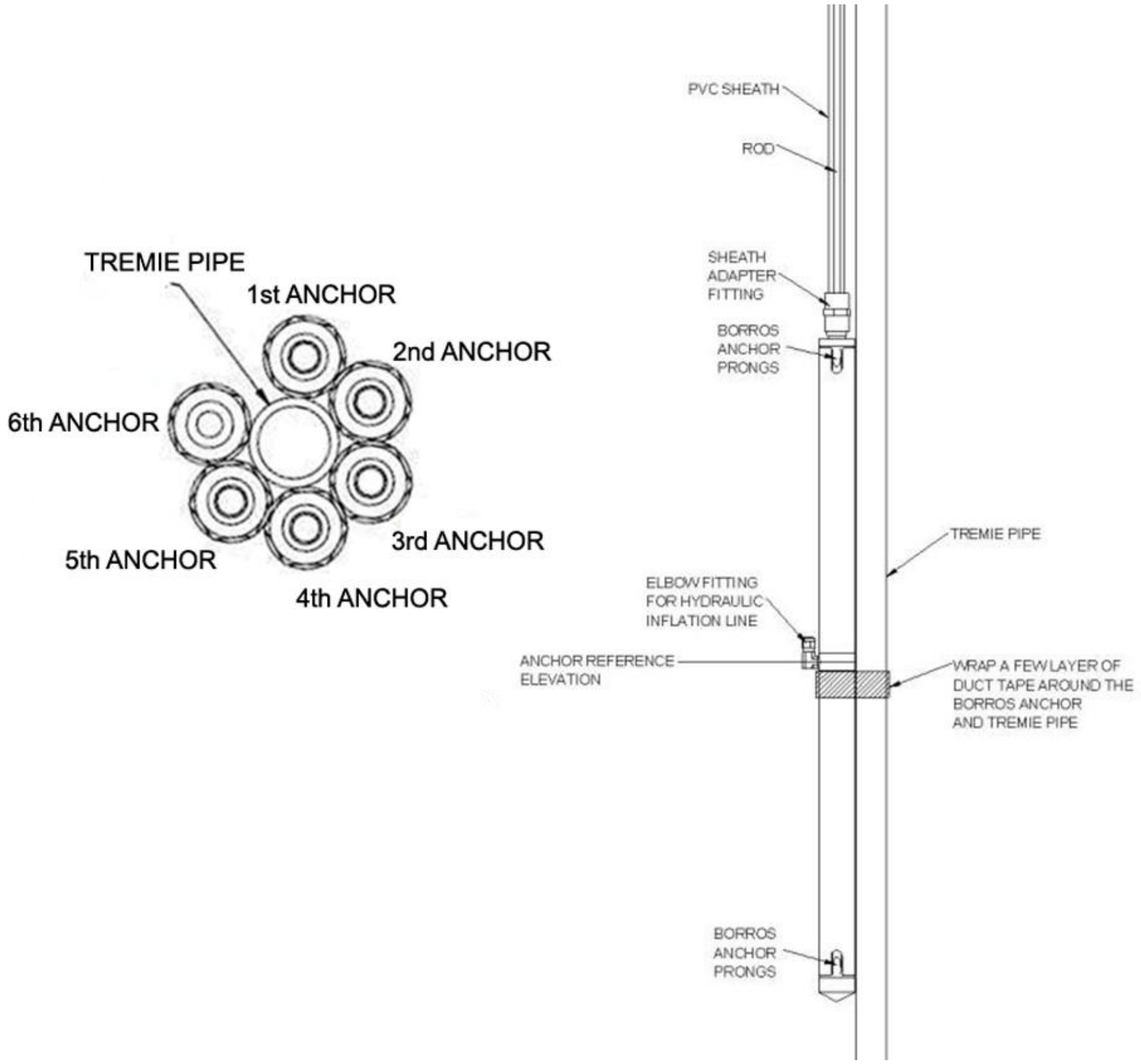
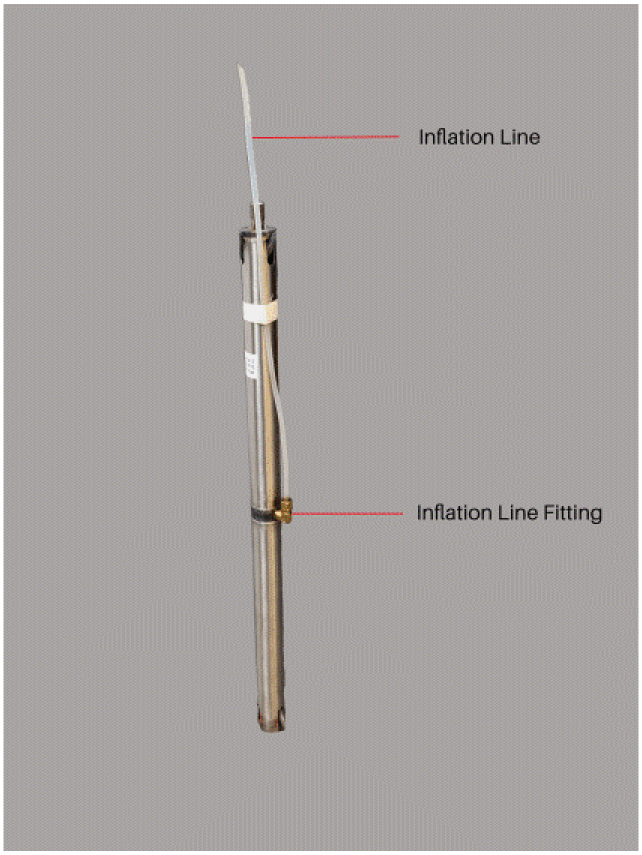


Figure 13: Top and Side View of Borros-Type Anchors Attached to Central Tremie Pipe

3. Attach an inflation line to the fitting on each anchor with enough length to span the designated depth of that particular anchor, +3m for surface slack.



4. Remove the slack in the inflation line by taping the inflation lines away from the opening of the prongs. Tape the inflation lines securely to the PVC sheathing to avoid puncturing when the prongs protrude out.

NOTE: Inflation lines should be well-marked, as to which anchor they belong to, so that the anchor deployment can be done in sequence from the lowest anchor to the topmost anchor.

5. Lower the assembly into the borehole section by section until all anchors are in their respective elevations, as per the plan from Section 7.6.

NOTE: For upward or downward-directed installations with an incline, the inflation lines should be prefilled before connecting to anchor. Pre-filling is optional for vertical downward-directed installations.

6. When the entire Extensometer assembly is in position and the anchors are ready to be deployed, connect the inflation line to a hand pump, starting from the lowest anchor to the topmost anchor.
7. Pump hydraulic oil into the inflation tube until the anchors' prongs have fully opened and penetrated the sides of the borehole. Continue to pump oil until the inflation tube bursts (around 2000 – 2500 psi).
8. Trim the inflation line and continue to activate the next anchor until all anchors are activated.
9. Once all the anchors are deployed, refer to Appendix A for instructions on grouting the borehole.

CAUTION: Keep a firm hold on the Extensometer during this process. Do NOT release the anchor and rod assembly, even when all the anchors have been deployed, if the borehole is to be grouted.

7.8 INSTALLING GROUT COLLAR

After filling the borehole with grout (Appendix A), follow these steps to install the grout collar:

1. Before the grout sets, place the aluminum Grout Collar into the borehole collar with approximately 75mm (3") of Grout Collar sticking above the borehole surface (see Figure 15).

NOTE: Install the grout collar after all the anchor and rod assemblies are lowered into the borehole and the borehole is filled with grout.

The top of the grout's surface holds the collar in place until the hand pack seal is added.

RST recommends waiting a day to top off the grout to better control the top surface and then adding the hand pack seal to the top of the grout.

The large vent hole should be above the borehole's surface (oriented upwards if the borehole is inclined) to ensure proper venting during the grouting process.

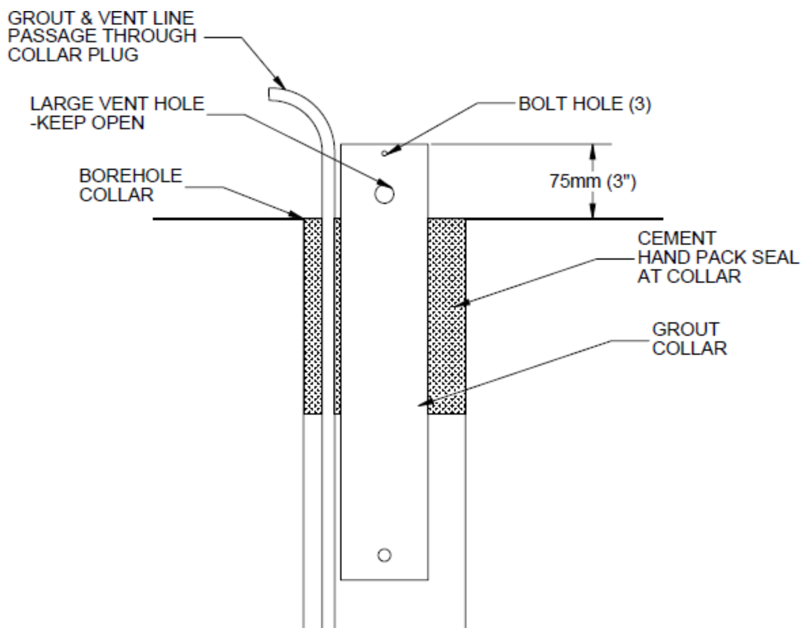


Figure 14: Grout Collar Installation

2. Securely hold the anchor and rod assemblies in place if they are freely hanging in the borehole.

3. The grout collar needs to be firmly attached to the borehole collar so that a reliable fixed measurement reference point is established.

4. Once the grout sets, after a day or two, it will shrink, and the grout surface level drops anywhere from a few inches to one foot. Replenish the grout and allow it to set, sealing with hand pack seal afterwards.

7.9 INSTALLING EXTENSOMETER HEAD AND ADJUSTING RANGE

1. Ensure the grout collar is securely in place once the grout in the borehole is set. The top of the grout collar will be the reference zero mark.

2. Trim the tremie pipe and vent line (if used) as short as possible inside the borehole.

3. Determine the heave (compression), in millimeter, anticipated with the Extensometer system.

4. Using a pipe cutter, trim the PVC sheaths so they are flush with the grout collar.

⚠ **CAUTION**: Do not trim the Extensometer rods yet.

---

5. Measure the Extensometer rods to ensure all of them protrude beyond the grout collar by at least:

   i. 30 inches (≈ 76 cm) for the 50 mm/100 mm sensor range Extensometer system

   ii. 45 inches (≈ 76 cm) for the 150 mm/200 mm sensor range Extensometer system

6. Measure the height of the Extensometer head to check if it differs from the measurement below:

   i. 618 mm/24 inches for 50mm/100mm sensor range Extensometer system

   ii. 991 mm/39 inches for 150mm/200mm sensor range Extensometer system

7. Trim excess Extensometer rod length. Extensometer rod should be sticking out of the grout collar surface by the “Extensometer head height” subtracted from “the initial setting for compression anticipation”.

   For example:

   100mm sensor range Extensometer system with 25mm of compression anticipation.

   Extensometer Rod length sticking out the Grout Collar = 618mm – 25mm

   = 593mm.

→ **NOTE**: Mark the anchor number using a felt marker pen to avoid confusion.

→ **NOTE**: Complete steps 8 – 14 while referring to Figure 15, illustrating the internal components of the Rigid Rod MPBX.

---

8. Slide the Extensometer head onto the Extensometer rods and PVC sheaths into the grout collar. Align the rods with the appropriate hole number as stamped at the top of the extensometer head.
9. Insert the Extensometer rods through the corresponding holes as aligned in Step 8 and continue to slide the rods past the sensor/rod adapter.
10. Tighten the hex bolts to secure the Extensometer head to the grout collar.
11. Connect the cable to a readout to confirm if the correct length of shaft is pulled out by reading the “B” value on the readout and cross reference with the calibration data.
12. Adjust the VW displacement transducer to the desired extension/compression measurement setting by pulling the transducer shaft away from the transducer.
13. Tighten the set screw on the sensor adapter block to lock the extension/compression measurement setting.

⚠ **CAUTION**: Do not rotate the shaft as this can damage the sensor.

---

14. Slide the PVC cover back onto the Extensometer head and lock it in place by tightening the screws on the side.

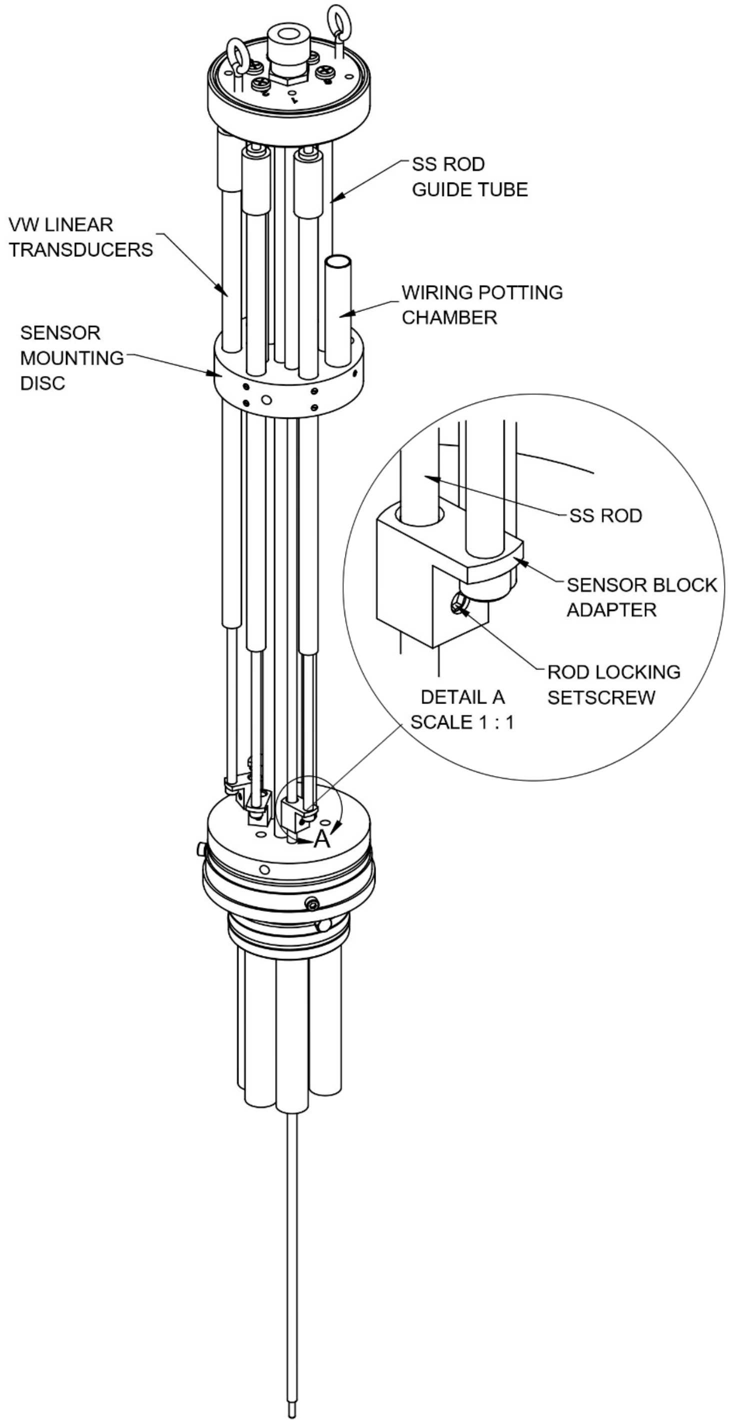


Figure 15: Internal Components of the Rigid Rod MPBX

8 TAKING READINGS

NOTE: If using any other third-party readout, please refer to the specific readout's instruction manual before operation.

1. Record the Serial Number of the MPBX marked on the top of the reference head. Serial numbers for individual sensors are provided with the calibration certificate and summary document upon delivery of the MPBX system.

2. Ensure the MPBX cable's wires are connected to a VW2106 Readout, RSTAR Affinity Logger, DT Logger, or FlexDAQ as per wiring Connection table below. Set B Sweep to 1200 – 3550 Hz.

Table 1: Wiring Connection Color Code

Cable Color Code							
Cable Type	**Sensor 1 Coil**	**Sensor 2 Coil**	**Sensor 3 Coil**	**Sensor 4 Coil**	**Sensor 5 Coil**	**Sensor 6 Coil**	**Thermistor**
EL360008 (For 1-3 Sensors)	Red & Black	Orange & Blue	Yellow & Brown	N/A	N/A	N/A	Green & White
EL380007P (For 4-6 Sensors)	Red & Black	Orange & Blue	Yellow & Brown	Grey & Violet	Tan & Pink	White & Black	Green & White

3. Turn on the readout unit and the displacement will output data in digits called B units (Frequency Hz^2 / 1000).

4. Look up the Calibration Factor found on the calibration sheet for that sensor to convert the B unit readings to engineering units (i.e. mm).

5. The readout unit will also output temperature data in °C. If an ohmmeter is used directly on the green and white wires, the equation and/or table in Appendix B can be used to calculate/derive the temperature in °C.

8.1 TAKING READINGS WITH A DEPTH MICROMETER

1. Record the Serial Number of the MPBX marked on the top of the reference head. Serial numbers for individual sensors are provided with the calibration certificate and summary document upon delivery of the MPBX system.

2. Insert the depth micrometer into hole/anchor #1 until its base sits flush on top of the reference head. The hole/anchor identifier number is stamped on the top of the reference head.

3. Turn the knob of the depth micrometer, lowering the feeler gauge into the hole until it clicks, indicating that it has reached the top of the rod.

4. Record the corresponding reading.

5. Repeat steps 2-4 for the remaining holes/anchors of the MPBX system.

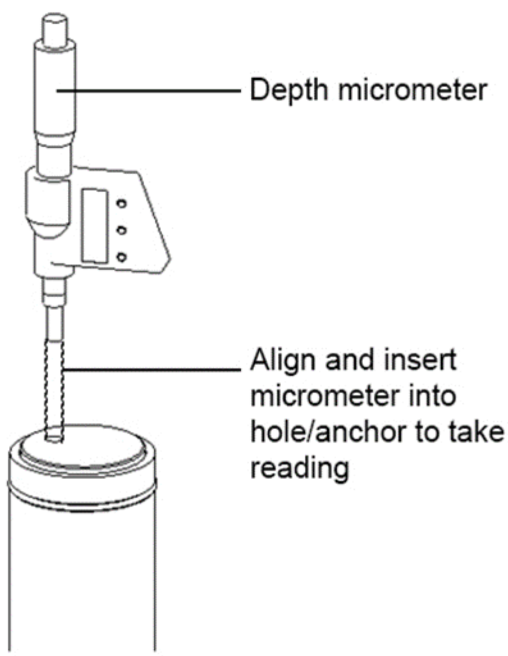


Figure 16: Taking Readings with a Depth Micrometer

9 DATA REDUCTION

Linear Displacement Equation:

$$Displacement = CF(L - L_0)$$

Where:

CF	=	Calibration Factor (mm/B unit)
L	=	Current Reading (B units)
L_0	=	Initial (at installation) Reading (B units)

Polynomial Displacement Equation:

$$Displacement = A(L^2) + B(L) + C + K(T - T_0)$$

Where:

A	=	Polynomial Gauge Factor (in mm/(B unit)^2)
B	=	Polynomial Gauge Factor (in mm/B unit)
C	=	Polynomial Gauge Factor (in mm)

NOTE: Polynomial Gauge Factor C is calculated using the following formula:
$C = -[A(L_0^2) + B(L_0)]$

L	=	Current Reading (B units)
K	=	Temperature Correction Factor (mm/°C)

NOTE: See Equation 3 to calculate the Temperature Correction Factor.
Positive displacement value = extension
Negative displacement value = compression

Current Anchor Elevation = Initial Anchor Elevation + Displacement

NOTE: Typically, this is done for each anchor after converting from B units to Engineering units.

10 PRODUCT SPECIFICATIONS

Item	Specification
Sensor	
Sensor Range	50, 100, 150, 200 mm
Accuracy	+/- 0.25 % FSR
Resolution	0.02% FSR
Linearity	0.50% FSR
Electrical	
Operating Temperature	-20°C to 80 °C
Thermal Zero Shift	<0.05% FSR/°C
Mechanical	
Number of Anchors	1 to 6
Borehole Diameter	recommend minimum 4” (101 mm)

11 SERVICE, REPAIR AND CONTACT INFORMATION

This product does not contain any user-serviceable parts. Contact RST for product services or repairs.

- For sales information: sales@rstinstruments.com
- For technical support: support@rstinstruments.com
- Website: www.rstinstruments.com
- Toll free: 1-800-665-5599

RST Canada Office (Head Quarters)

Address: 11545 Kingston Street, Maple Ridge, BC, Canada V2X 0Z5

Telephone: 604-540-1100

Fax: 604-540-1005

Business hours: 7:30 a.m. to 5:00 p.m. (PST) Monday to Friday, except holidays

RST UK Office

Address: Unit 4 Charles Industrial Estate Stowupland Road, Stowmarket
Suffolk, UK, IP14 5AH

Telephone: +44 1449 706680

Business hours: 9:00 a.m. to 6:30 p.m. (GMT) Monday to Friday except holidays

APPENDIX A: GROUTING THE BOREHOLE

The grout that will be injected into the borehole is a homogenized mixture of cement and water made according to the usual grouting procedures. The cement/water ratio depends on stiffness of the surrounding ground. To ensure compliance of the grout with the surrounding ground, it is generally necessary to cast test specimens to confirm the grout stiffness and deformability. In the case of highly fissured rock, it may be necessary to seal the fissures, to grout and drill the hole prior to the installation of the Extensometer or to use mechanical anchors. Once grouting is completed, make sure that grout tube that exceeds from the MPBX has been cut.

Making cement-bentonite grout in the field is a straightforward process. The most effective mixing is commonly done in a barrel or tub with the drill-rig pump, circulating the batch through the pump in 50-to-200-gallon quantities. The rig pump provides the kind of jet-mixing required to get the job done quickly. Any kind of bentonite powder used to make drilling mud combined with Type 1 or 2 Portland cement and water can be used, but the appropriate quantity of bentonite will vary somewhat depending on grade of bentonite, mixing sequence, mixing effort (agitation), water pH and temperature.

Grout mixes should be controlled by weight and proportioned to give the desired strength of the set grout. The conversion factors contained in Appendix H.10 in Dunnicliff (1988, 1993) are very helpful in mix design. Two mixes are given in Table 2 that vary in 28-day strength from 50 psi to 4 psi for water-cement ratios of 2.5 to 6.6 respectively.

Application	Grout for Medium to Hard Soils		Grout for Soft Soils	
Materials	Weight	Ratio by Weight	Weight	Ratio by Weight
Water	30 gallons	2.5	75 gallons	6.6
Portland Cement	94 lbs. (1 sack)	1	94 lbs. (1 sack)	1
Bentonite	25 lbs. (as required)	0.3	39 lbs. (as required)	0.4
Notes	The 28-day compressive strength of this mix is about 50 psi, similar to very stiff to hard clay. The modulus is about 10,000 psi.		The 28-day strength of this mix is about 4 psi, similar to very soft clay.	

Table 2: Cement-Bentonite Grout Recipe

NOTE: Water and cement and mixed in first, followed by bentonite.

DOWNWARD DIRECTED BOREHOLES

Grouting is completed when the injected grout emerges from the borehole. After sufficient time has elapsed for curing of the grout, the Extensometer head is checked to ensure that it is adequately grouted in place. Additional mortar may be hand placed around the head if required.

UPWARD DIRECTED BOREHOLES

An installation into an upward directed borehole requires special means to support and apply the necessary lift force to position the Extensometer. Extra care should be taken to ensure that the full weight of the Extensometer assembly is supported prior to grouting operation. The easiest way is to secure the latter with wood wedges and to make a tight cap at the borehole collar level with oakum sealant and quick setting cement. The safest way to secure the Extensometer in place is with a wood support tightly anchored to the surface surrounding the borehole using tie bolts.

The grouting must be done only when the anchor head is securely attached to the head of the borehole. The shortest tube is used for injection; the longest is the vent tube. For long Extensometers, the cement plug may not be resistant enough to support the weight of the grout column. In that case, it may be necessary to inject in two stages. A second injection tube is necessary in that case. The first stage consists of pumping enough grout to reinforce the cement plug located at the Extensometer head. Once the grout has set, the rest of the borehole can be injected through the second tube. Grouting is completed when the material injected emerges from the vent tube. After sufficient time has elapsed for the curing of the grout, the Extensometer head is checked to ensure that it is adequately grouted in place. Additional mortar may be hand placed around the head if required.

NOTE:

- The grout consistency will vary depending upon type of bentonite used, water content, pH level of water, temperature and mixing method. The amount of bentonite hence required to reach appropriate consistency will hence vary.
- A Marsh Funnel can be used to ensure proper grout consistency. Ideal time ~ 55 seconds.

Contact RST instruments for further details and support.

APPENDIX B: TEMPERATURE CONVERSION

The following equation may be used to convert the measured thermistor resistance R (Ω) into temperature T (°C):

$$T = \frac{1}{1.4051*10^{-3} + 2.369*10^{-4}*\ln(R) + 1.019*10^{-7}*(\ln(R))^3} - 273$$

Equation 1: Thermistor Temperature Derivation

Alternatively, the values may be looked up directly in the table below:

Table 3: Thermistor Resistance (Ohms) and Temperature (deg. C)

Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp	Ohms	Temp
201.1K	-50	16.60K	-10	2417	+30	525.4	+70	153.2	+110
187.3K	-49	15.72K	-9	2317	31	507.8	71	149.0	111
174.5K	-48	14.90K	-8	2221	32	490.9	72	145.0	112
162.7K	-47	14.12K	-7	2130	33	474.7	73	141.11	113
151.7K	-46	13.39K	-6	2042	34	459.0	74	137.2	114
141.6K	-45	12.70K	-5	1959	35	444.0	75	133.6	115
132.2K	-44	12.05K	-4	1880	36	429.5	76	130.0	116
123.5K	-43	11.44K	-3	1805	37	415.6	77	126.5	117
115.4K	-42	10.86K	-2	1733	38	402.2	78	123.2	118
107.9K	-41	10.31K	-1	1664	39	389.3	79	119.9	119
101.0K	-40	9796	0	1598	40	376.9	80	116.8	120
94.48K	-39	9310	+1	1535	41	364.9	81	113.8	121
88.46K	-38	8851	2	1475	42	353.4	82	110.8	122
82.87K	-37	8417	3	1418	43	342..2	83	107.9	123
77.99K	-36	8006	4	1363	44	331.5	84	105.2	124
72.81K	-35	7618	5	1310	45	321.2	85	102.5	125
68.30K	-35	7252	6	1260	46	311.3	86	99.9	126
64.09K	-33	6905	7	1212	47	301.7	87	97.3	127
60.17K	-32	6576	8	1167	48	282.4	88	94.9	128
56.51K	-31	6265	9	1123	49	283.5	89	92.5	129
53.10K	-30	5971	10	1081	50	274.9	90	90.2	130
49.91K	-29	56.92	11	1040	51	266.6	91	87.9	131
46.94K	-28	5427	12	1002	52	258.6	92	85.7	132
44.16K	-27	5177	13	965.	53	250.9	93	83.6	134
39.13K	-25	4714	15	895.8	55	236.2	95	79.6	135
36.86K	-24	4500	16	863.3	56	229.3	96	77.6	136
34.73K	-23	4297	17	832.2	57	222.6	97	75.8	137
32.74K	-22	4105	18	802.3	58	216.1	98	73.9	138
30.87K	-21	3922	19	773.7	59	209.8	99	72.2	139
29.13K	-20	3748	20	746.3	60	203.8	100	70.4	140
27.49K	-19	3583	21	719.9	61	197.9	101	68.8	141
25.95K	-18	3426	22	694.7	62	192.2	102	67.1	142
24.51K	-17	3277	23	670.4	63	186.8	103	65.5	143
23.16K	-16	3135	24	647.1	64	181.5	104	64.0	144
21.89K	-15	3000	25	624.7	65	176.4	105	62.5	145
20.70K	-14	2872	26	603.3	66	171.4	106	61.1	146
19.58K	-13	2750	27	582.6	67	166.7	107	59.6	147
18.52K	-12	2633	28	562.8	68	162.0	108	58.3	148
17.53K	-11	2523	29	543.7	69	157.6	109	56.8	149
								55.6	150

APPENDIX C: TEMPERATURE CORRECTION

Temperature correction may not be necessary in many cases as the MPBX has a small coefficient of thermal expansion.

Temperature corrections may be applied for maximum accuracy or when temperature fluctuations are greater than 10°C.

$$Corrected\ Linear\ Displacement = CF(L_c - L_i) + K(T_c - T_i)$$

Equation 2: Linear Displacement Calculation

Enter the appropriate values into Equation 2 to calculate the displacement and convert the readings into linear units.

All subsequent readings should be subtracted from the initial reading to calculate the distance the crack has opened, where:

L_C	Current reading	[B-unit]
L_i	Initial reading	[B-unit]
CF	Linear Calibration Factor (see calibration sheet)	[mm/B-unit]
T_C	Current temperature	[°C]
T_i	Initial temperature	[°C]
K	Temperature Factor (see Equation 3)	[mm/°C]

Use the following equation to calculate K, the Temperature Correction Factor:

$$K = CF[(L_c * M) + B]$$

Equation 3: Temperature Correction Factor Calculation

L_C	Current reading	[B-unit]
M	Slope, see Table 4	[1/°C]
B	Constant. See Table 4	[B-unit/°C]
CF	Linear Calibration Factor, (see calibration sheet)	[mm/B-unit]

Table 4: Temperature Correction Factor Calculation Variables

Stroke (mm)	50	100	150	200
Slope (M)	0.000311	0.000399	0.000359	0.000306
Constant (B)	-0.2758	-0.8128	-0.5579	-0.4498

Sample calculation:

Assuming the following measurements from a 150mm sensor:

L_C	3762	[B-unit]
L_i	4791	[B-unit]
CF	0.0291788	[mm/B-unit]
T_C	22.5	[°C]
T_i	13.3	[°C]
M	0.000359	[1/°C]
B	-0.5579	[B-unit/°C]

First, calculate the Temperature Correction Factor:

$$K = CF[(L_c * M) + B]$$

$$\mathrm{K} = (0.0291788) * [(3762 * 0.000359) + (-0.5579)]$$

$$\mathrm{K} = (0.0291788) * (0.792658)$$

$$\mathrm{K} = 0.023129$$

Next, apply K to find the corrected Linear Displacement:

$$Corrected\ Linear\ Displacement = CF(L_c - L_i) + K(T_c - T_i)$$

$$= [(0.291788) * (3762 - 4791)] + [(0.023129) * (22.5 - 13.3)]$$

$$= (-1029 * 0.291788) + (0.023129 * 9.2)$$

$$= -\mathbf{29.81\ mm}$$

APPENDIX D: SAMPLE CALIBRATION RECORD

Calibration Record

RST Instruments Ltd., 11545 Kingston Street, Maple Ridge, BC, Canada V2X 0Z5
Tel: 604-540-1100 • Fax: 604-540-1005 • Toll free: 1-800-665-5599 (North America only)
www.rstinstruments.com

Vibrating Wire Multi-Point Borehole Extensometer

Model Number:	EMPBX003
Calibration Date:	August 17, 2024
Serial Number:	[redacted]
Mfg number:	[redacted]
Range:	200.0 mm
Temperature:	23.0 °C
Sales Order Number:	[redacted]
Cable Length:	5 m
Cable Type:	EL360008
Cable Colour Code:	Red/Black (Coil), Green/White (Thermistor)
Thermistor Type:	3 kΩ

Applied Displacement (mm)	First Reading Up (B units)	Second Reading Up (B units)	Average Reading (B units)	Calculated Linear (mm)	Linear Error (% FS)	Calculated Polynomial (mm)	Polynomial Fit (% FS)
0.00	2866	2864	2865	-0.09	-0.04	0.03	0.01
40.00	3764	3761	3762	39.96	-0.02	39.94	-0.03
80.00	4661	4662	4662	80.11	0.05	80.01	0.01
120.00	5560	5556	5558	120.12	0.06	120.03	0.01
160.00	6451	6453	6452	160.03	0.01	160.00	0.00
200.00	7346	7343	7345	199.87	-0.06	199.99	-0.01
				Max Error (%)	0.06		0.03

This instrument has been calibrated using standards traceable to the NIST in compliance with ANSI Z540-1

Linear Calibration Factor (CF): 4.4640E-02 mm/B unit, Regression Zero (at Calibration): 8629.6 B unit

Polynomial Gauge Factors:

A: 4.4554E-08 mm/(B unit)^2 B: 4.4185E-02 mm/Bunit C: Calculated (see below)

Users must establish site zero readings for calculation purposes. **Polynomial C (mm) = - [A(L_0^2) + B(L_0)]**

Displacement is calculated using the following equations:

Linear: $D = CF\,(L - L_0)$

Polynomial: $D = A(L^2) + B(L) + C + K\,(T - T_0)$

L_0, L = initial (at installation) and current readings, in B units
T_0 ,T = initial (at installation) and current temperature, in °C
B units = B scale output of VW 2102, VW 2104, VW 2106, and DT 2011 readouts

B units = Hz^2 / 1000 i.e. 1700 Hz = 2890 B units

Calibrated by: [redacted] Date: [redacted]