PROCEDURE FOR

FSEL INSTALLATION OF STRAIN GAGES ON PRESTRESSING STRANDS

1. PROCEDURE OVERVIEW

This procedure is to be used for installation of bonded strain gages on prestressing strand. It includes necessary materials and a recommend practice for surface preparation, installation, and protection of strain gages.

Actual installation of the strain gage itself is a relatively minor portion of this procedure. The majority of this procedure is related to waterproofing and mechanical protection of the gage. These items are needed to ensure the gage will survive the concrete casting process.

Gages are typically placed on the exterior faces of the exteriors wires in a strand. The gage is placed to align with the helical exterior wires rather than the longitudinal axis of the strand (Figure 1). Therefore, the strain indicated by the strain gage will not necessarily be equivalent to the axial strain in the strand. To ensure proper interpretation of the helical strain data, additional testing may be necessary.

Figure 1 – Photograph of a strain gage on a helical wire

1.1. Student Responsibilities:

- Read and understand the requirements of this procedure
- Provide strand for instrumentation
- Acquire all materials for strain gage installation

1.2. Staff Responsibilities:

- Read and understand the requirements of this procedure
- Assist students with installation as needed

2. EQUIPMENT AND TOOLS

There are two primary suppliers for strain gages at FSEL: Texas Measurements (http://www.straingage.com/) and Micro Measurements (http://www.vishaypg.com/micro-measurements/). Texas Measurements is an importer of gages manufactured by Tokyo Sokki Kenkyujo (http://www.tml.jp/e/).

Lead times for purchasing gages vary wildly. Occasionally gages are in stock in the U.S. and can be shipped right away. Often gages are not in stock and occasionally gages must be sent from Japan to local suppliers. In that case, lead times can be 2 to 3 months. Historically, Micro Measurements has had a longer lead-time than Texas Measurements. It is recommended that the supplier be contacted prior to ordering to get estimated lead times.

2.1. Gages Purchased from Texas Measurements

The typical gage for prestressing strand is FLA-5-11-5LT. This gage is a 5-mm general-purpose, uniaxial gage that is temperature compensated for mild steel. It has a pre-attached 3-lead wire that is 5 m long. In some cases, a narrower gage may be needed to ensure the gage fits onto a helical wire.

2.2. Gages Purchased from Micro Measurements Strain Gages

The typical gage for prestressing strand is C2A-06-250LW-350.

2.3. Materials from Texas Measurements

- CN adhesive
- SB Tape
- VM tape
- Epoxy Overcoat (Hardman Epoweld 8173, Part A & Part B)

2.4. Materials from Micro-Measurements

- M-Coat A
- Gage Installation Tape (PCT 2M)

2.5. Materials Generally Available at FSEL

- Pneumatic Angle Die Grinder
- Fine Sanding Disc
- Non-Woven Sponges
- Razor Blade or Utility Knife
- Digital Multimeter
- Electrical Tape
- Zip Ties

2.6. Additional Materials

- Acetone

3. PERSONAL PROTECTIVE EQUIPMENT

▪ Safety Glasses ▪ Safety Shoes ▪ Dust Mask ▪ Rubber Gloves

4. DETAILED PROCEDURE

4.1. Mark the area of the strand to be gaged.

Typically, an area about 1 to 2 in. long is sufficient for gage installation.

4.2. Using a fine sanding disc on a pneumatic angle die grinder, polish the wire surface in preparation for gage bonding.

*The sanding required for this step should be done with extreme care. A small defect caused by grinding can lead to rupture of the wire or strand. If strain gages are being applied to a strand already under stress, precautions **must** be taken to protect personnel should a strand rupture.*

4.3. Clean the wire surface using acetone and non-woven sponges.

Wet the sponge thoroughly with acetone and wipe across the polished area. Repeat the process with fresh sponges and wiping in one direction until the non-woven sponge remains white after wiping. Be careful not to wipe the sponges through a dirty un-polished area into the clean, polished area.

Note that acetone is a highly flammable material and should be handled accordingly. Wear safety glasses to protect your eyes from acetone. Long-term exposure to acetone vapors is harmful and at a minimum, can cause headache and dizziness. Use acetone in a properly ventilated area and avoid breathing in acetone vapors.

4.4. Mark the gage location

Mark the final gage location with a pencil or marker. The mark should be adjacent to the freshly cleaned area, i.e. not in the gage installation region, to avoid contamination.

4.5. Attach the strain gage.

For satisfactory bonding of the gage to the wire, it is essential that the wire surface be completely clean prior to gage installation. If there is a delay between surface preparation steps described above and the gage installation, carefully inspect the surface and repeat the cleaning steps as needed. Re-applying acetone is highly recommended to remove the collected dust on the surface. Using the fine sanding disc might also be needed for delays that are longer than 1 to 2 days.

Attaching the gage consists of a number of smaller steps. These steps need to be done quickly and smoothly to ensure a reliable bond between the gage and the substrate.

4.5.1. Identify the top and bottom surfaces of the strain gage before removing it from the packaging.

The "top" of the strain gage has the visible metallic wires printed on it. The "top" of the gage will also have the lead wires attached to it; these can be seen in Figure 1. The printed wires are visible from the "bottom," but they will be dull in color.

Do not touch the bottom surface of the strain gage, as it would contaminate the bonding surface.

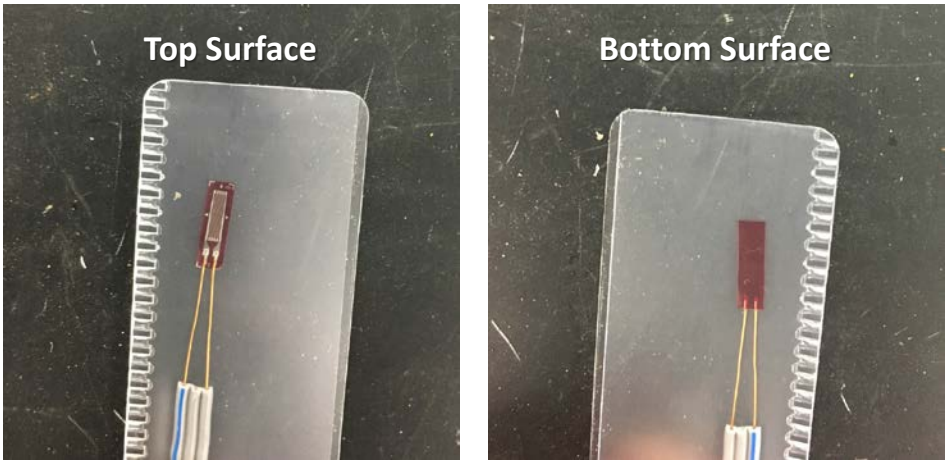

Figure 2 – Identifying the top of the gage

4.5.2. Remove the gage from the protective plastic and apply a piece of gage installation tape to the top of the gage without touching the bottom of the gage.

The tape serves two purposes: 1) it allows handling of the gage without touching it and 2) it helps position the gage on the specimen for gluing. The piece of tape should be 2 to 3 in. long with the gage centered in the strip of tape.

The gage can be temporarily placed on a clean glass surface to apply the tape. If this technique is used, the glass surface needs to be completely cleaned before placing each gage, preferably using acetone.

4.5.3. Position and tape the gage on the wire.

Using the tape to handle the gage, position the gage over the polished and cleaned area of the wire. Press the tape to the strand to temporarily hold the gage in place. Inspect the position of the gage and reposition using the tape as needed.

4.5.4. Partially peal back the tape to expose the bottom surface of the gage.

Starting with the end of the tape near the strain gage lead wires, slowly peel the tape from the strand. Stop peeling the tape once the complete gage is expose. The portion of the tape beyond the gage should be left adhered to the strand to allow the gage to be returned to its previous location.

4.5.5. Apply one drop of CN adhesive to the junction between the peeled back tape and the wire.

4.5.6. Slide a finger or thumb from the attached end of the tape to the free end of the tape in a smooth and continuous motion to press the gage into the adhesive and force out air bubbles.

4.5.7. Maintain pressure on the tape and gage for approximately 1 minute to allow the adhesive to set and harden.

Adhesive drying times are affected by ambient temperature and humidity.

4.5.8. Carefully remove the tape from the gage and wire.

Peel back the tape from the end of the gage opposite the lead wires. The tape must be peeled back slowly and carefully to avoid damaging the gage or lead wires.

4.5.9. After removing the tape, inspect the gage for unbonded areas.

Unbonded areas will appear as air bubbles or areas of a slightly different color than the bonded areas. If the unbonded areas are on the edges of the gage, more adhesive can be added. If more adhesive is added, reapply pressure to allow the adhesive to cure.

4.5.10. Using a razor blade or utility knife very carefully debond the lead wires from the wire.

The adhesive will likely have glued the exposed lead wires to the wire underneath. The wires can be freed by using a utility knife.

4.5.11. Apply electrical tape to the area below the exposed lead wires.

When doing this step, be careful not to peel off any portion of the strain gage. The lead wires can be carefully bent 180 degrees to allow room to apply the electrical tape. The tape should be placed as close to the edge of the gage as possible. This step can be omitted if necessary as the exposed lead wires will be further separated from the wire in a later step of the installation.

4.6. Apply waterproofing and mechanical protection to the gage.

Since the gage and strand will be placed in fresh concrete and that concrete will be consolidated with vibration, the gage will need both waterproofing and mechanical protection.

4.6.1. Apply a coating of M-Coat A to the strain gage, exposed lead wires, and surrounding area using the brush provide. Allow 15 to 10 minutes for the coating to dry.

It is recommended that three layers of M-Coat be used for each strain gage. Each coating layer needs to dry before applying the next layer.

4.6.2. Cut a strip of SB tape long enough to wrap around the strand and the strain gage.

4.6.3. Completely wrap the strand and gage with SB tape, peel off the paper backing.

4.6.4. Press the SB tape onto the strand making sure to seal the seam in the SB tape and to seal the SB tape to the strand.

Ensure that the SB tape is pressed into the interstices between the helical wires.

4.6.5. Fold the exposed lead wired on top of the layer of SB tape applied in Article 4.6.4 and lightly press the wires into the SB tape.

In this step, the lead wires should be bent 180 degrees from their original direction before embedding in the SB tape.

4.6.6. Place another small piece of SB tape on top of the exposed lead wires to encapsulate them.

The bare lead wire should be completely encapsulated in SB tape. Only the insulated portion of wire should be visible after this step.

4.6.7. Completely cover the SB tape with a single wrap of VM tape.

4.6.8. Wrap the VM tape with electrical tape.

4.6.9. Mix a small amount of epoxy overcoat (Hardman Epoweld 8173) per the directions provided on the bottle.

4.6.10. Coat the entire strain gage area as defined by the electrical tape with a thin layer of epoxy and allow the epoxy to set and cure.

This epoxy forms a hard layer that improves mechanical protection of the gage during concrete casting.

4.7. Wire protection.

The wires also need mechanical protection in case the wire is pulled during concrete casting.

4.7.1. Using a zip tie, tightly attach the wire to the strand at the location where it exits the layer of epoxy.

4.7.2. Make a small loop in the lead wire by wrapping it ground a finger.

4.7.3. Using a second zip tie, secure the far end of the looped wire to the strand a short distance from the zip tie applied in Article 4.7.1. Do not completely tighten the second zip tie.

This will create a small loop in the wires. If the wire is accidentally pulled during casting, the loop will protect the gage from tension.

4.7.4. Trim the free ends of the zip ties close to the connections.

4.8. Check the electrical resistance of the gage and ensure the gage is not electrically connected to the strand.

It is recommended that the electrical connectivity of the gage be checked prior to casting concrete. If the checks below indicate a problem, the gage will likely need to be removed and replaced with a new gage.

For typical strain gages, three lead wires are attached to each gage. One of these three wires is independent and the remaining two are connected to each other. For gages purchased from Texas Measurements, the independent wire is in a gray sheath marked with a blue stripe and the two connected, or dependent, wires are in unmarked, gray sheaths. For gages purchased from Micro Measurements, the independent wire is red and the dependent wires are black and white.

4.8.1. Check electrical resistance between the independent wire and each of the dependent wires.

Using a multimeter set to measure resistance, connect the independent wire to one of the probes of a multimeter. Connect one of the dependent wires to the other multimeter probe. These connections can be made by firmly pressing the bare wires to the multimeter probes. The measured resistance should approximately match the nominal resistance of the gage (120Ω or 350Ω).

4.8.2. Check the electrical resistance between each of the three lead wires and the strand.

One at a time, connect each lead wire to a multimeter probe while holding the other multimeter probe to the bare strand. The multimeter should read "OL" for overload, indicating a very high resistance. The overload indicates the gage is electrically isolated from the strand as it should be.

4.9. Label all strain gage wires and bundle them together.

The lead wires must extend outside the concrete volume prior to casting. Typically, the wires are secured in bundles to nearby strands using zip ties. The free end of the bundle should be appropriately positioned to minimize interference with concrete casting and finishing operations.

4.10. Record the gage factor for the gage.

When setting up the data acquisition system, the gage factor will be needed to convert voltage measurements to strain values.

5. SUPPORTING DOCUMENTS

None.

6. REFERENCED DOCUMENTS

None.

7. RECORD OF REVISIONS

Revision	Date	Affected Pages	Description
0	2016-09-23	All	Initial Issue