

The Secret Recipe for Weldable Sensors for Structural Health Monitoring (SHM)



Author: Dani Honas, Bridge Diagnostics, Inc. (BDI)

Structural health monitoring (SHM) systems provide accurate and near-real-time information regarding the performance and condition of structures, such as bridges, buildings, dams, tunnels, wind turbines, and more. The cornerstone of many SHM systems is the foil strain gage, in both bondable and weldable forms. Bridge Diagnostics, Inc.'s (BDI) strain gage of choice for field applications is the Micro-Measurements weldable foil strain gage. In this case study, BDI provides step-by-step procedures for properly installing the devices and "Tricks of the Trade" the company has learned and been practicing for nearly 30 years.

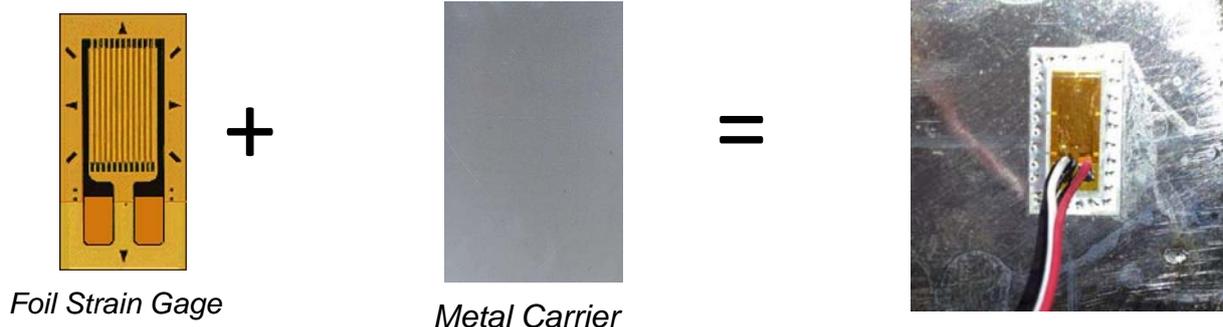
Company/Institute: Bridge Diagnostics, Inc. (BDI)

Industry/Application Area: Structural Health Monitoring (SHM)

Products Used:

- [Weldable Foil Strain Gages](#)
- [700 Welding & Soldering Unit](#)

What is a Weldable Foil Strain Gage?



Structural Health Monitoring (SHM) is a catch phrase for monitoring of any infrastructure. SHM can be applied to bridges, buildings, dams, tunnels, wind turbines, industrial facilities, and even light

poles. SHM systems provide accurate and near-real-time information regarding the performance and condition of structures. It will never replace visual inspection and human judgement, but if properly deployed, it can be used to keep a “remote eye” on critical structures. It helps minimize inspection cycles, alerts engineers to any changes, and aids in planning and designing maintenance activities. This increases safety, reduces uncertainty, and lowers operating expenses.

One of the most common SHM sensors in use today is the foil strain gage. Typically the smallest instrument on site, the foil strain gage, in both bondable and weldable form, is the cornerstone of many SHM systems.

This “user’s manual” is a step-by-step procedure of how to install BDI’s strain gage of choice for field applications: the weldable foil strain gage. BDI has outlined “Tricks of the Trade,” keys to properly completing installations that we have learned and been practicing for nearly 30 years of installing weldables. SHM is increasing with infrastructure owners, but every poor sensor installation adds ammunition for those skeptical of the proven benefits of SHM. BDI is committed to making progress in the field of SHM. By revealing our tricks for doing the job right, we can keep the SHM community moving forward.

Why Does BDI Use Micro-Measurements Weldables?

Traditional adhesively bonded foil strain gages are extremely difficult to properly install in outdoor heavy civil environments. Weldables minimize the potential for error and improve the survivability of these field-installed strain gages. Some of the advantages for weldables include:

- *Efficiency:* A traditional adhesively bonded strain gage can take upwards of 30 minutes or more per location, versus five minutes for a weldable strain gage.
- *Environment:* Cold, wet, or dirty conditions are a source of contamination within the glue line. By removing adhesives, the majority of the strain gage performance issues disappear.
- *Access:* Traditional adhesive preparation materials include a grinder, sand paper, conditioner, neutralizer, gauze, cotton swabs, etc. Weldables require only a grinder and a welder. In hard-to-reach areas where space is limited, minimizing the amount of material needed at the instrumented location makes the field engineer’s task easier.
- *Gage Protection:* Pre-protected weldables can be purchased off-the-shelf. These will typically perform better in long-term applications than field-applied coatings.
- *Bureaucracy/Politics:* With chemicals comes paperwork. Paperwork is not only required to get materials to the site, but on site as well. By removing chemicals from the process, hazardous shipping and OSHA HazComm protocols are no longer required.

Remember to Use Caution!



With welding comes sparks. Users must be aware of their working conditions. In most instances, weldables are the ideal option; however, working in a flammable or explosive environment may require more traditional techniques. It is the user's responsibility to understand his or her conditions and ensure all work is carried out in a safe manner, for both personnel and the instrumented structure.

The Challenge

To benefit from the advantages of weldable strain gages while yielding consistent and accurate measurements, certain details must not be overlooked throughout implementation.

The User Explains

The nine essential steps for how to properly install a weldable foil strain gage:

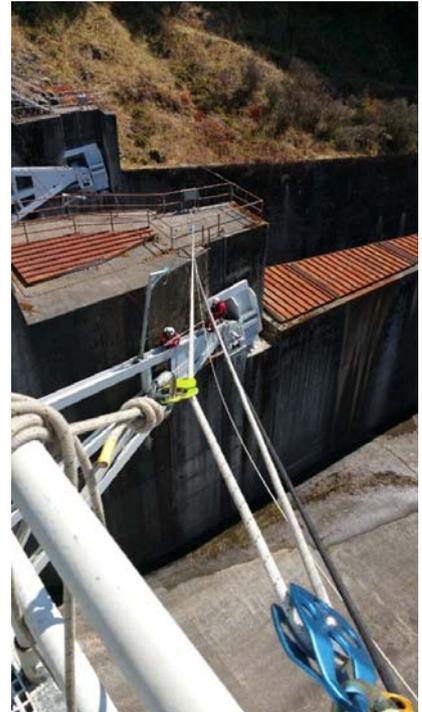
1. Accessing the Instrumented Location

Accessing the instrumented location can often be the hardest part of the process, though it is typically overlooked. There are risks associated with every type of access, whether done with a manlift, "snooper," ropes, boat, or ladder. The installer should be briefed and comfortable with his or her access method. It is imperative that the job be done safely.

Tricks of the Trade:

- *Be prepared.* Nothing wastes more time in the field than getting to the instrumented location and finding out a tool is missing. Have a pre-assembled toolbox with a checklist of what is required to complete the task. Before leaving your preparation location, run through the checklist and ensure everything is in the toolbox and in good working order.
- *Have extras.* If there is a possibility of dropping something, put it on a lanyard. If a lanyard makes a small or specialized tool too awkward to use, take an extra.





2. Measure and Mark Out Gage Location

Measure out the specified gage location.

Inspect this area for any deep pitting or surface abnormalities and alter the gage location as required.

Mark out the location with two perpendicular and intersecting lines; this will pinpoint gage location as well as orientation.

Tricks of the Trade:

- *Write the dimensions, orientation, and gage location designation on the surface near the instrumented location.* If you forget to document your installation the first time, this makes it easy to recover the information.
- *Take a picture.* If someone questions the installation, a photo provides proof of installation quality as well as gage location. Together with documented installation data, this step prevents the necessity of a second trip to the site to recover the information.
- *Extend lines past the preparation area.* If the marks are all ground away, then time is wasted relocating the instrumented location.



3. Surface Preparation

Ensure the surface is dry and free of contaminants like grease, oil, etc. With a coarse sanding wheel (80-120 grit), grind the gage location and surrounding area to remove paint, rust, pitting, and other surface imperfections. With a finer sander (220+ grit), regrind at the gage location until a smooth, uniform, “polished” finish is achieved. Ensure that the sanded area is large enough for the entire length of the strain sensor as well as your protection.

Tricks of the Trade:

- *Make sure your marks are still visible after grinding to prevent the need for re-measuring.*
- *Use a battery grinder, not corded.* These spin slower and remove less base material.
- *Be mindful of what you are grinding.* If extensive pitting is present, it may be better to move the gage than remove significant base material.



4. Re-Mark Gage Location

Using the marked lines outside the sanded area, connect the collinear segments into a single line.

The point of intersection between each set of perpendicular lines represents the same gage location that was marked out before surface preparation.

Tricks of the Trade:

- *Make sure the marking utensil has a good point.* Utensils with blunt or damaged tips undermine accuracy.



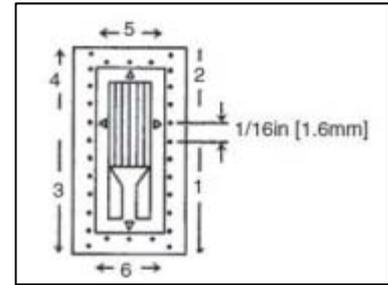
5. Weldable Sensor Installation

Tape the gage down to the surface so that the two marked lines run down the middle of the length and width of the gage. After completing Part 1 of the welding pattern, inspect that the gage is positioned properly. Remove the tape. Complete welding per the provided Micro-Measurements welding pattern.



Tricks of the Trade:

- Follow the Micro-Measurements specified welding pattern. Otherwise, the installation may “wrinkle” and not lay flat against the base material.
- After completing Part 1 and 2 of the weld pattern, apply a small amount of pressure to the entire gage while welding Part 3. This will ensure the gage is flat.



6. Attach Lead Wires

Like adhesive bonding, an environment that is anything less than ideal makes lead wire attachment difficult. The same care given to weldable gages and procedures should be taken with soldering.

Tricks of the Trade:

- Always try to use pre-attached lead wires whenever possible to minimize time and field problems. Cold solder joints are hard to avoid when working in an uncomfortable and awkward position.
- Add a fatigue/service loop before connecting the wire to the gage. This keeps the gage from being pulled by the wire and leaves a little extra wire if the gage ever has to be replaced.



7. Cable Management

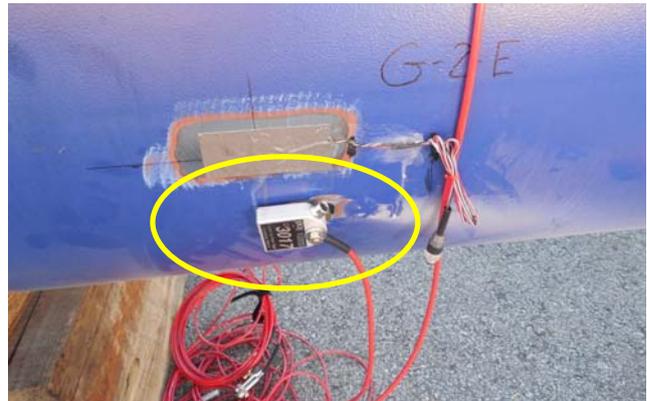
Cables are what people are going to see, so it is important to make them look professional. Cables should be bundled, zip-tied, and tied to the structure at no more than five foot intervals for temporary installations. Cables should be run in conduit for all permanent installations.

Tricks of the Trade:

- Always label cables with a unique identifying number on both ends. If a cable is broken, it can always be re-run from the gage location.



- Point cable exits down where possible, to minimize paths for water.
- Put a “drip loop” in cable, so water collects and drips off instead of running into the sensor protection.
- “Connectorize” the strain gage lead wires to the bridge completion unit, to further minimize field soldering.



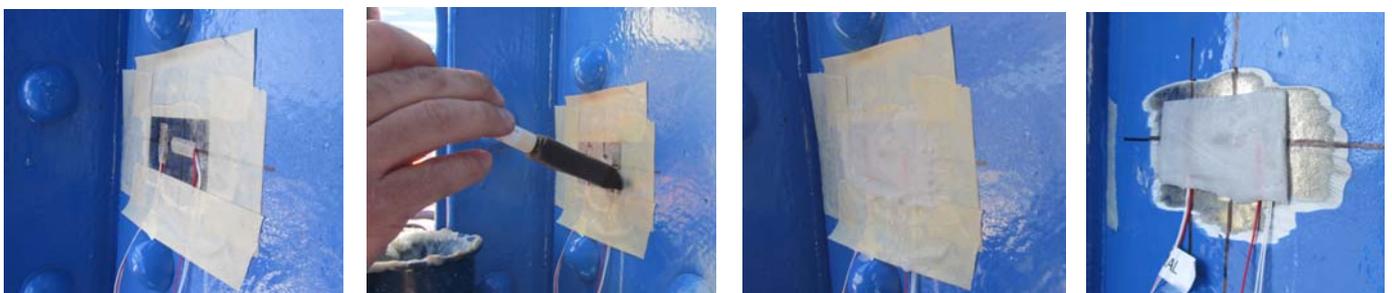
8. Protective Coating

There are a large variety of protective coatings that can be used when shielding a strain gage sensor installation. Based on the environment, an appropriate protective coating should be selected.

Apply protective coating over the gaging area. Welds and the carrier must also be covered.

Tricks of the Trade:

- When possible, use a manufacturer-protected weldable gage, like the Micro-Measurements LEA series.
- Isolate the sensor installation by applying tape around the installation area. Although this is not necessary, it makes the job look more professional.
- Protective coating must be adhered to the base metal, not paint. Overlapping the protective coating over the paint may cause an unknown chemical reaction between the two materials or, at minimum, may result in low-coating adhesion. Bare steel can be touched up with zinc spray paint or another owner-approved material.
- Always discuss protective coating with your Micro-Measurements representative to ensure the proper material is used.



9. Final Checkout



Many data acquisition systems will complete this process automatically, or a Micro-Measurements 1300 Installation Tester can be used to test strain gage sensors individually. The user should always:

- Bridge balance
- Insulation resistance
- Polarity
- Shunt calibration



“With Micro-Measurements weldable foil strain gage sensors, BDI is able to provide efficient structural health monitoring as well as testing services and equipment.”

Acknowledgement

BDI provides efficient structural health monitoring and load testing services and equipment all over the world. In addition to providing bridge load testing and analysis services, BDI manufactures the BDI-STS, which has been developed specifically for the purpose of testing highway bridges and other structures subjected to live loads.

Last but not least, BDI would like to thank Jim Johnson from Micro-Measurements for his endless guidance and support.

Contact Information

Bridge Diagnostics, Inc.
1995 57th Court North
Suite 100, Boulder, CO
80301-2826 USA
Phone: (303) 494-3230
Fax: (303) 494-5027
E-mail: scotta@bridgetest.com
Web: <http://bridgetest.com/>

Vishay Precision Group, Inc. (VPG)
Micro-Measurements
mm@vpgsensors.com

