Instructions for Using BDI Transducer Extensions on Reinforced Concrete Structures

Special gage-lengthening extensions have been designed for use with BDI Strain Transducers in order to measure surface strains on reinforced concrete (R/C) structures. The aluminum extensions simply increase the transducer gage length to allow an "averaged" strain value to be recorded in the presence of cracks associated with most R/C structures. These units make available seven additional gage lengths, each one an integer multiple of the original 3-inch (76.2mm) transducer gage length.

There are three items to consider when selecting an appropriate gage length for a particular R/C member. The first is that it must be long enough to minimize the effects of flexural cracks. There are several factors that control crack formation in concrete, primarily the beam depth, steel ratio, concrete strength, and bond strength. While there are no precise methods for determining a minimum crack spacing, it has been determined experimentally that a gage length equal to the member depth (d) is satisfactory for slabs and rectangular beams and 1.5 times d is suitable for T-beams. The second item to consider is that the gage length be short enough that the measured strains are not significantly affected by moment gradients. An upper limit of $1/20^{th}$ the span length (L) will usually maintain the gradient below 5%. In general, it is desired to obtain as long a gage length as possible without exceeding the upper bound. The following table provides the recommended lower and upper gage length limits for R/C members.

Member Type	Lower Limit	Upper Limit
Slabs and Rectangular Beams	1.0 x d	L / 20
T-Beams	1.5 x d	L / 20

The third item is the available strain range of the transducer. As the gage length is progressively increased, the force on the transducer imposed by the extension is increased as well for a given amount of strain. This has the effect of reducing the available strain range for the transducer/extension assembly. The upper limit of the strain range recommended for aluminum transducers is approximately ±4000 με. However, to minimize the force in the system and to avoid the mounting tabs from popping off the concrete members during loading, BDI recommends keeping the maximum strain in the transducer to about 1,000με. Therefore, the following table has been developed to indicate the maximum strain ranges for each available gage length. Higher strains can of course be measured, however, special attention should be paid to the gain settings on the data acquisition equipment being used. If the load is going to be very heavy, we recommend that the gain level for the STS be set to 500. It should be noted that in most cases, the live-load strain magnitudes recorded by BDI on reinforced concrete structures have been less than 100με.

Multiple of Original Length	Actual Gage Length w/ Extension	Maximum Strain Range	Approx. Conc. Stress for f''_c = 3,000 psi	Approx. Conc. Stress for f''_c = 4,000 psi	Approx. Conc. Stress for f''_c= 5,000 psi	Approx. Steel Re-bar Stress
1	3 in (76.2 mm)	±1000 με.	3.1 ksi	3.6 ksi	4.0 ksi	30 ksi
2	6 in (152.4 mm)	±500 με.	1.6 ksi	1.8 ksi	2.0 ksi	15 ksi
3	9 in (228.6 mm)	±330 με.	1.0 ksi	1.2 ksi	1.3 ksi	9.9 ksi
4	12 in (304.8 mm)	±250 με.	780 psi	900 psi	1.0 ksi	7.5 ksi
5	15 in (381.0 mm)	±200 με.	625 psi	720 psi	800 psi	6.0 ksi
6	18 in (457.2 mm)	±160 με.	500 psi	575 psi	650 psi	4.8 ksi
7	21 in (533.4 mm)	±140 με.	440 psi	500 psi	560 psi	4.2 ksi
8	24 in (609.6 mm)	±125 με.	390 psi	450 psi	500 psi	3.8 ksi

Once a gage length has been determined, there are three possible scenarios for mounting the transducer/extension assemblies to the structure:

1) Adhesive/tabs on both ends. If conditions are dry, the concrete surfaces relatively smooth, and testing will not last more than a day, the tab/adhesive system will usually work fine as described below.
2) Adhesive/tab on transducer end and an anchor or masonry screw on the extension end. This is the preferred method of BDI. Again, if conditions are dry, then the adhesive/tab system on one end will be

sufficient for a couple of day's worth of testing, as long as the other end is securely mounted with a mechanical anchor. It is highly recommended to use masonry screws such as the blue "TapCons" (readily available at most hardware stores) to install transducer/extension assembly due to the additional weight of the extension.

3) Anchor/masonry screw on both ends. Use this approach only when the structure is wet and/or very rough.

In either of the above scenarios, the steps below should be followed for mounting the extensions to the transducers. The extension jig is used to ensure that the transducer is aligned properly with the extension. If using the anchor mounting on both ends, then omit the mounting tabs described below.

1) Using an extension jig as seen in Figure 1, insert a tab into slot. Set the transducer over the tab into the transducer hole closest to the cable exit and **LOOSELY** thread on a nut.

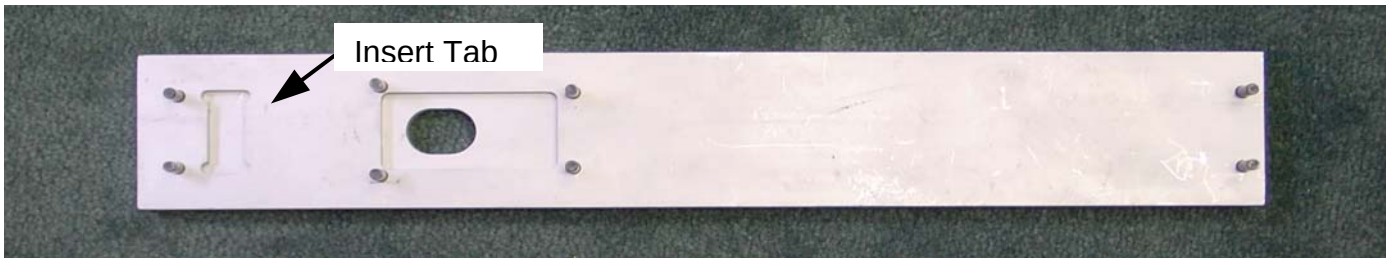

Figure 1

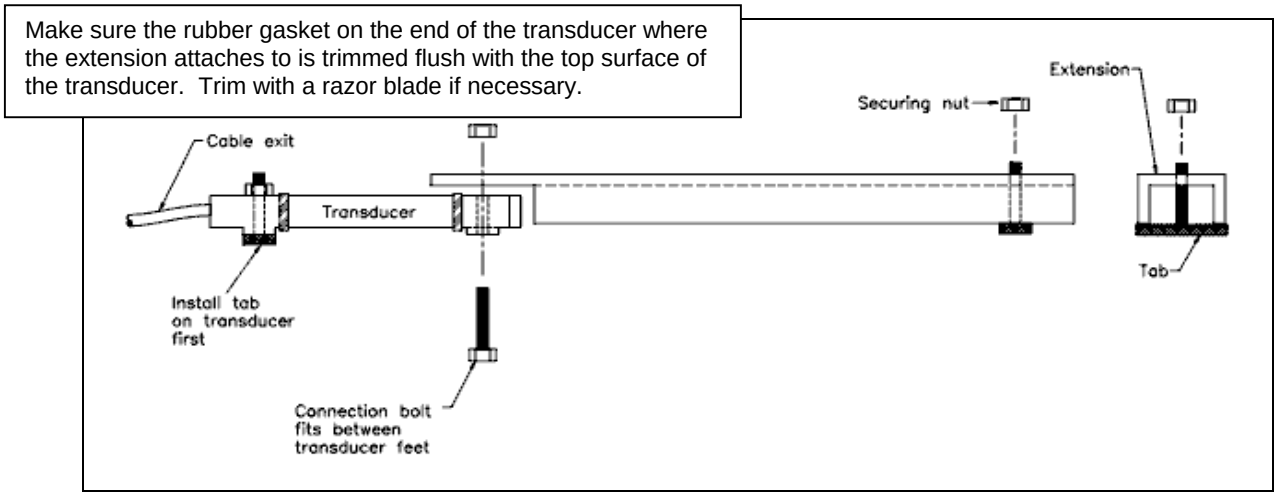

Figure 2

2) Place the special extension bolt in the mounting hole on the other end of the transducer. The hole cut in the extension jig allows for the insertion of the bolt into the transducer while it is still in the jig. The head of the bolt has been machined on two sides which should fit between the "feet" of the transducer.

3) Hold the bolt in place and slide the extension over the extension bolt and **LOOSELY** thread on a nut.

4) **GENTLY** compress the assembly to the tab end of the jig as seen in Figure 3. Once the transducer and extension have been aligned and any "looseness" removed from the assembly, tighten both the tab and extension bolts to approximately 50 in-lbs.

5) If using the tab-adhesive system on both ends of the assembly, install a tab into the desired hole on the extension, and hold in place with a pair of vise-grips while tightening the nut as shown in the figure.

The tab should be installed at a right angle to the extension. The assembly is now complete until it is time to install the gage.

Figure 1

IMPORTANT: Once the extensions have been installed, the transducers are much more susceptible to damage during handling due to the large extension "lever". To minimize possible damage, place the transducer/extension assemblies in a plastic five-gallon bucket with the extension ends down. This way, many assemblies can be carried at once and still be relatively protected.

Mounting Transducer/Extension Assemblies to the Structure

The preferred method of using a masonry screw on one end and the tab/adhesive method on the other end will be described here.

1) Locate the gaging point on the structure and make two marks approximately 2 feet apart along the axis of where the transducer/extension assembly is to be mounted. It can sometimes be difficult to align the marks on the bottom of concrete slab structures, particularly if the structure is skewed. Often, a series of marks is laid out on the bottom of the slab and a chalk line is used to lay out a grid, making gage alignment very easy. Another alternative is to use a laser chalk line to temporarily create a line while the gage is installed.
2) Temporarily hold the transducer/extension assembly up to where it is to be mounted to ensure that there are no obstructions along the length of the unit. Make small marks at the two mounting points, one for the transducer end and one for the selected gage length on the extension end.
3) Using a concrete drill, drill a 5/32" hole at the extension end mark. For the tab end, it is possible that the concrete surface will need to be smoothed slightly with a grinder to ensure that the tab is making good contact with the structure. Be sure to wipe all grinder dust clear from the location using a rag or paint brush.
4) Install the masonry screw and washer through the selected hole on the extension, and install two or three fender washers over the screw (supplied with extension) as needed to ensure that the assembly will not be touching the bottom of the structure along it's length.
5) Using a power screwdriver, start the masonry screw into the hole until the assembly is temporarily held up into place, yet allowing access to the bottom of the tab.
6) Apply adhesive to the tab and push unit to mounting location. Pull back tab, leaving a patch of adhesive on the structure.
7) Apply accelerator to the adhesive, and quickly put assembly in place and tighten masonry screw with the power screwdriver. Hold the tab end of the unit in place by hand for several seconds until the adhesive has hardened. A final check on the tightness of the masonry screw is then made with a box-end wrench.

Note that in many locations, the STS boxes can be set on the ground and connected to the Intelliducers. However, sometimes this is not possible and the STS boxes must be hung up on the structure as illustrated above. Small sheet metal angles with baling wire work well for this purpose and can be obtained at any hardware store. Or, if drilling is being done for concrete anchors, often the boxes can be hung from one of the inserted anchors with some baling wire.

It may be noted during testing that there is significantly drift due to ambient temperature changes once the extensions are installed. This is due to the relatively low thermal inertia of the transducer/extension assembly compared to that of the concrete structure. The best solution is to run the tests on a day when the temperature is remaining constant. This is not always possible, therefore, particularly for assemblies that receive direct sunlight (on top of the deck, on the parapet, etc.), the drift can be minimized by covering the gage and extension with an insulating material. Often, a temporary cover of foam or cloth attached with duct tape can protect them from wind and direct sunlight. Alternatively, BDI can provide custom gage covers that can be mounted temporarily.

After the test has been completed, extreme care must be taken in removing the securing nuts from the tabs, as often tabs will have a tendency to “twist off” at the glue line, particularly if the concrete is slightly rough. Do not attempt to remove the extension from the transducer while the assembly is still mounted to the structure. Also, before the assemblies are removed, double-check that the gage length used for each transducer is recorded. If this is not done, the data will be useless!

Back off the securing nut between the transducer and extension by holding the extension only. If the tabs are still attached to the transducer or extension after removal from the structure, use vice grips to hold the bottom of the tab while the securing nut on top is removed. Again, never use the transducer as a lever!!!

To reduce the strain data, remember that the recorded strains have been “amplified” by the integer multiple of the gage length. For example, if the longest possible gage length is used (24 in, 58.8cm) this is eight times the standard gage length. Therefore, the data will need to be divided by eight to arrive at the correct “averaged” strain. In addition, a factor of 1.1 will need to be applied to the output to account for the extension effect. The BDI WinGRF software has features to easily handle these operations.