TECHNOLOGY BRIEF

When bonds are too rigid - the case against bonded pairs

When bonds are too rigid, the result can be 'break' up and disappointment…

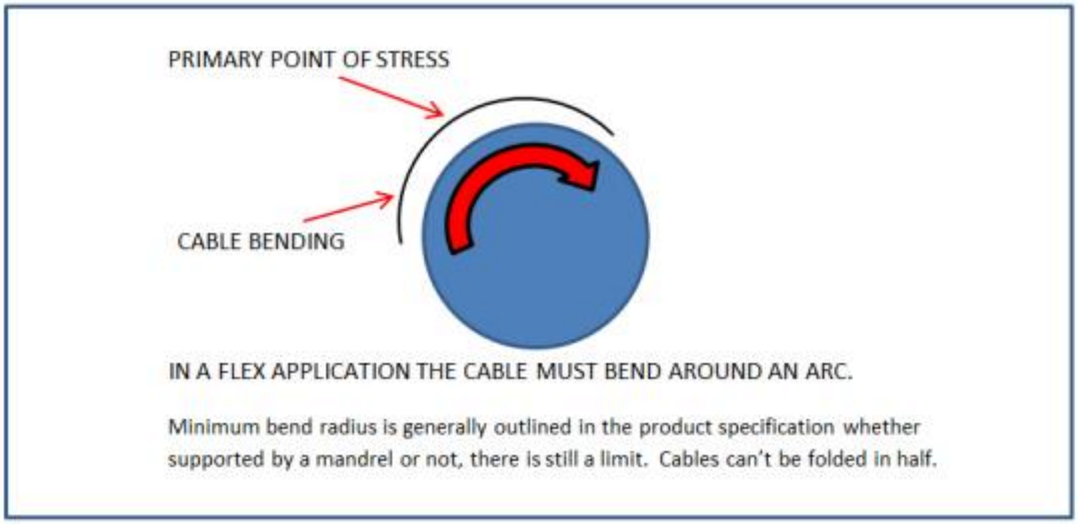
THE CASE AGAINST BONDED PAIRS IN A FLEX CABLE APPLICATION

This sounds like a cheap self-help book for relationships, doesn't it? Let me assure you, this isn't about dating or couples pairing. It's about the pairing of conductors in a high flex Ethernet cable and the resulting relationship to factory downtime.

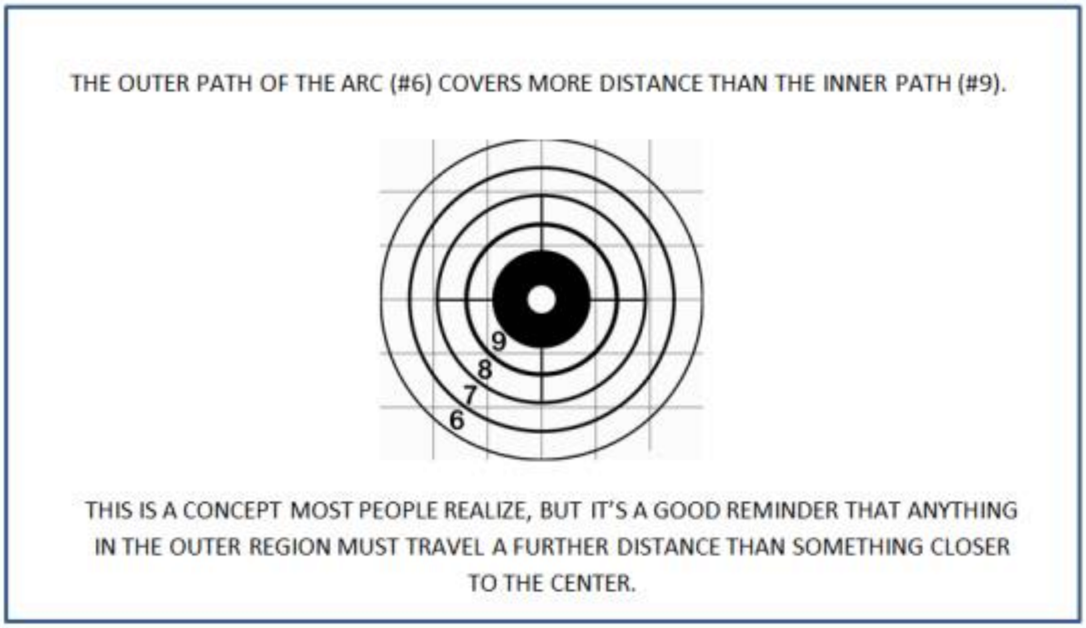
If you've been in the Ethernet connectivity game for any length of time, you've probably heard about bonded pairs and all the hype about how wonderful they are. They aren't new and in some cases, they do have benefits. Originally marketed for solid/horizontal commercial cable the bonded pairs do a couple of things. First they tend to hold the pairs together during the process of pulling the cable through walls. This may give the installer a better shot at a successful channel test when the job is complete. Secondly, the bonds hold the twist of the pair together "as the factory wants it" so even less experienced assemblers should get a passing termination with little or no re-work; something that isn't too tough with standard un-bonded pair cable either with a little practice. However, these bonded pair benefits were squarely aimed at the original user base, the commercial network installer.

As we've all witnessed, the economics of business can be a funny thing. If a company has made a commitment to a specific way of producing a product in high volume, there's an inertia factor pressuring the business to continue to do things the same way without variation in an effort to benefit from economies of scale. If Engineering believes there may be a better way, Finance and Production may resist adopting the change citing added costs and various hassles. Before you know it, the mandate comes down…"Make it all the same and use it for everything". This really isn't that uncommon a situation. The next thing that usually happens is the PR issue gets kicked down the road to Marketing where the resident spin-masters work their magic. Ultimately resulting in, "technique X" becoming the best thing since sliced bread for everything. When it comes to the concept of bonded pairs for a continuous flex Ethernet cable, we may be facing one of these scenarios because bonded pairs were never meant to be flexed.

As mentioned earlier, there may be some ease of assembly benefits with bonded pair cable. However, these are short lived because once the assembler gets up to speed with non-bonded pair cable they can easily produce fantastic results and high yield using either. Further, the focus of this paper is on industrial cord sets which are primarily assembled offsite by experienced assembly companies specializing in over-molded connectors. Therefore, ease of assembly isn't a concern of most system users. What they need to consider is the elimination of downtime once the system has been commissioned. This is where our research has shown the concept of bonded pairs to fall apart (literally). As previously discussed, bonded pairs were originally used for horizontal and patching applications in commercial/office environments. These applications have very limited flex, usually consisting of “one time” bends to facilitate installation. Conversely, the industrial automation environment is rife with continuous movement, flex applications. Let's examine what happens when a cable is repeatedly flexed and run that side by side with some common sense and a few illustrations.

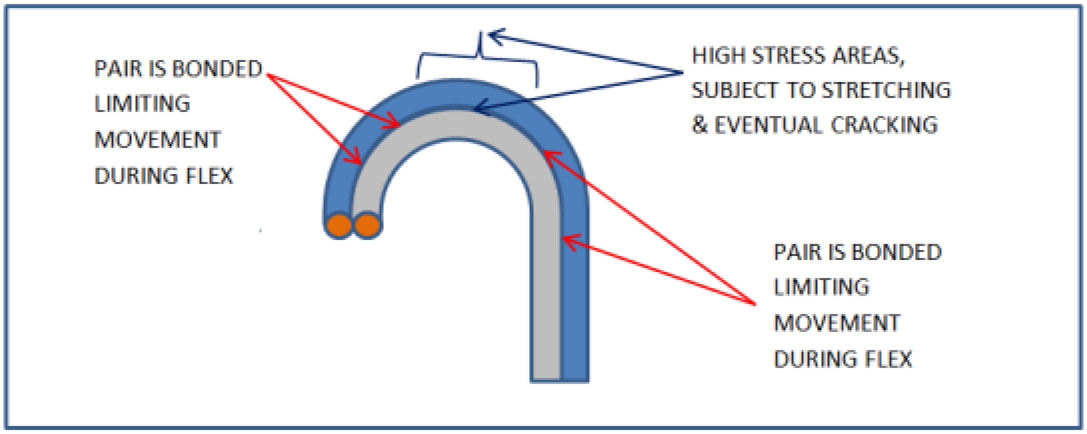


As shown above, when a cable flexes, it bends around an arc. Let's examine what's happening. The larger the arc around the center point, the greater the distance. Take a look at the illustration of the target below.

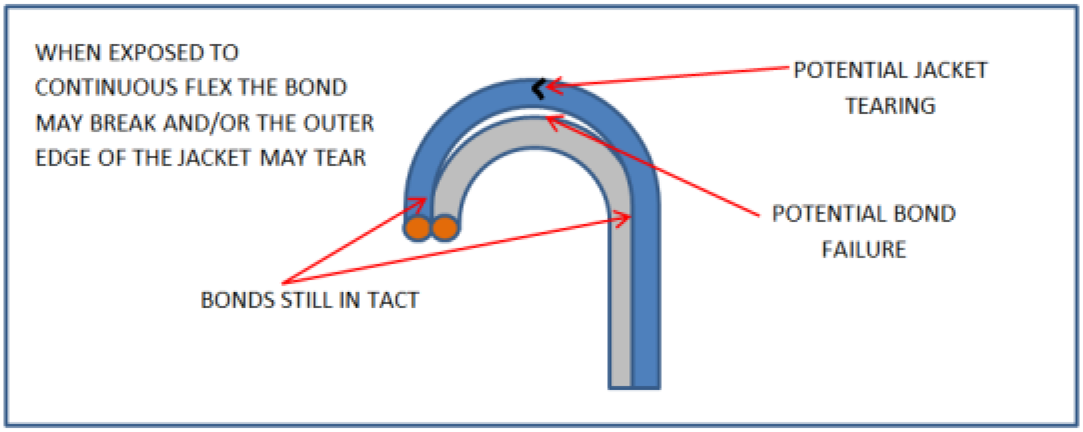


When objects are subjected to bending and flex forces, it's usually a benefit if they aren't completely rigid. For an example, we can use earthquake resistant buildings. Their foundations allow some sway and movement. The reason for this was learned from experience, completely rigid buildings tried to fight off the forces of an earthquake and wound up crumbling to the ground. The problem was they offered no “give”. Now take the example of a mature oak tree Vs. a young sapling. After a severe wind storm, the powerful Oak lays broken on the ground and the weak sapling is no worse for the wear. Why is this? The mature Oak tried to resist while the sapling bent and swayed in the wind, only to pop back up at the end unscathed. There are lessons to be learned here that apply to flex cable. Although a bonded pair may have some assembly benefits, the fact that the pairs are essentially glued together may end up being the weak link in a flex application. Bonded pairs can behave more like the mature oak than the sapling and here's why.

IN THE ILLUSTRATION ABOVE A SMALL SECTION OF BONDED PAIR CABLE (BETWEEN TWISTS) IS DEPICTED. SINCE THE PAIRS ARE BONDED TOGETHER, THEY ARE FORCED TO STAY TOGETHER DURING FLEX. THIS CAUSES STRESS IN THE INSULATION OF THE "OUTER" CONDUCTOR BECAUSE IT HAS TO REMAIN ATTACHED TO THE INNER CONDUCTOR, BUT AT THE SAME TIME TRAVEL (BEND AROUND) A LONGER DISTANCE.



When a bonded pair flexes around an unsupported bend there are two high stress areas to be concerned with as shown in the illustration above. The first is the area where the pairs are bonded and the second is the area around the outer most edge of the jacket. As discussed, the outer conductor of the pair has to travel a greater distance than the inner conductor and since it is attached to the inner conductor, it has no choice but to stretch. Secondly, the bonded area that holds the pair together has forces induced by the flexing of the cable that are trying to tear the bond between the conductors apart. In a static bend (one time bend for install) the bonded pairs hold together. However, after repeated flexing the bond will eventually fail leaving an area of the pair now un-bonded. Since the rest of the pair remains bonded, the cable still doesn't allow much movement except in the area of the failed bond. This tends to concentrate the majority of flex movement on a very small area of the conductor eventually leading to failure. These failures will spread down the cable over time as it continues to flex, eventually leading to a lapse in connectivity and down time.



For continuous motion flex applications, non-bonded pairs seem to have an edge over bonded pairs when it comes to life expectancy. Non-bonded pairs allow the individual conductors enough freedom of movement so they can accommodate the abuse of a flex application, however, they too must be protected. The best way that we've found to allow the individual conductors to slip over each other during motion, but still limit the pairs from moving too far apart is with a pressure jacket. Pressure jacketing is a totally different philosophy from using a classic “tube” jacket and bonding the pairs. Let's take a look at the differences.

A tube jacket is exactly what it sounds like, a tube surrounding the pairs in a cable. It has room within it for the pairs to move around and even untwist during certain circumstances. The way around this potential for untwisting is to bond the pairs together. As discussed earlier, this bonding is suitable for a commercial environment, but it isn't the best for an industrial flex application. In a flex application, it's desirable for the pairs to have the ability for some movement. This allows the individual conductors to accommodate the flex motion by essentially, “going with the flow”. However, the amount of movement should not be limitless. Therefore, the individual conductors in a pair must be held in check. This can be done using a “pressure jacket”. Essentially, a pressure jacket is created when the extrude head applying the jacket is run under higher pressure with more jacket material. The result is a thicker jacket that will not only protect and cushion the pairs while allowing movement, but will also limit the amount of conductor to conductor gap present in the pair. A further side benefit is that pressure jackets have a firm round profile that is crush resistant and perfect for obtaining a reliable seal with over-molded connectors.

Industrial applications are full of trade-offs and industrial cables are no different. Bonded pairs were developed for the commercial networking world, not specifically for harsh environments. Bonded pairs may help in assembly of a commercial cord for the office, but their benefits in factory automation are questionable. Yes, they do keep the pairs together during flex thus limiting the conductor to conductor gap in the pair and possibly giving a slight benefit to return loss. However, the conductor to conductor rigidness eventually leads to their destruction. Limiting conductor to conductor gaps to improve return loss may be good practice, but in a factory automation setting, survivability trumps this 100 fold. Especially since the conductor to conductor gap is minimal (photo #1) and nothing like the gross exaggeration being depicted in some marketing literature. Further, some conductor to conductor gap is desirable because it keeps the cable from self-destructing as it performs millions of flex cycles. We've found it is far better to allow some conductor to conductor movement and keep it in check with pressure jacketing. In fact, we've run our pressure jacketed industrial Ethernet cables through 10 million cycles in flex testing device that simulates an unsupported bend, much like the situation cables would be exposed to on a robotic arm. The fact that this is an unsupported bend makes all the difference in the world. An unsupported bend test is much more abusive than a C-Track or tick tock test, both of which add protection to the cable by supporting the bend. In fact when running a sample of bonded pair cable through the same unsupported bend test mentioned above, failure came in under 600,000 cycles. Giving up a little margin in return loss is better than field failures, and the reality is that conductor to conductor gaps in un-bonded pairs are minimal and return loss margin is ample. See below.

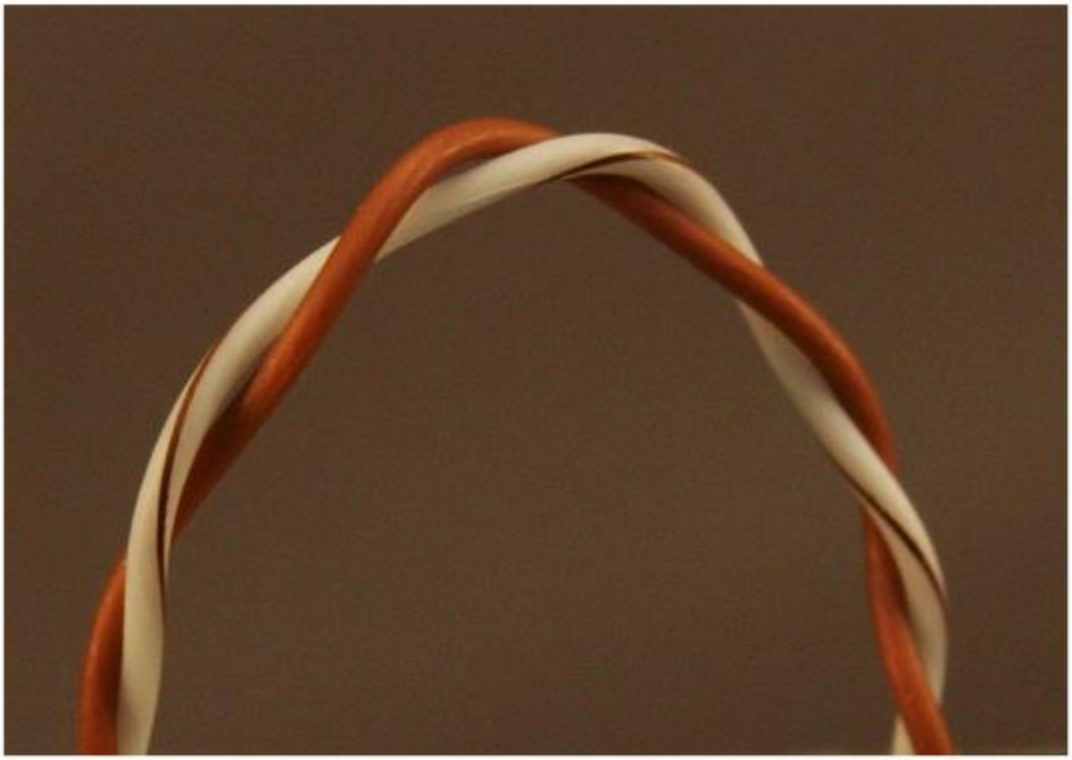


PHOTO 1: UN-BONDED PAIR BEING BENT IN AN ARC. NOTICE THE CONDUCTOR TO CONDUCTOR SEPARATION IS MINIMAL EVEN THOUGH THE PAIRS ARE NOT BONDED TOGETHER.

PHOTO 2 & 3: PHOTO OF BONDED PAIR AFTER LIMITED FLEXING. THIS SAMPLE WAS NOT FLEXED TO FAILURE BECAUSE IT CONVEYS THE ISSUE CLEARER AS IT BEGINS TO BREAK DOWN. NOTICE THE "WORK HARDENING" OF THE CONDUCTOR INSULATION AT THE TOP OF THE ARC. THE CABLE HAS CREASED AND NOW ALL BEND FORCES ARE BEGINNING TO CONCENTRATE IN AT THE ONE WEAK POINT. EVENTUALLY THIS WILL BECOME THE POINT OF FAILURE.

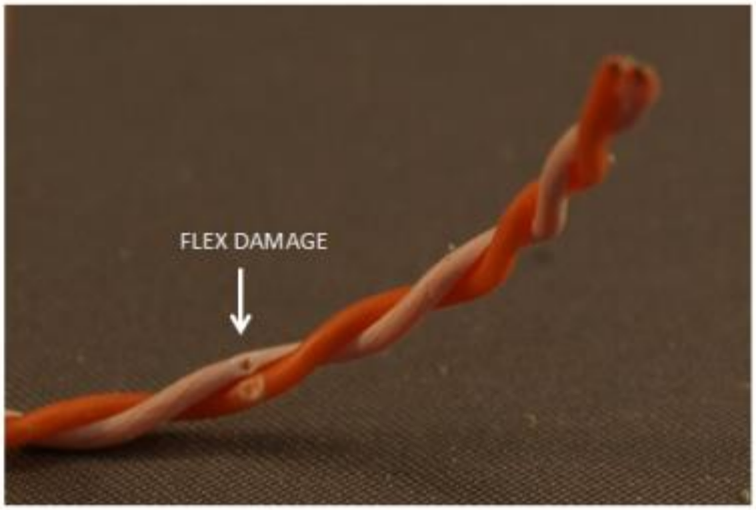


PHOTO 4: THIS PICTURE SHOWS THE UNDERSIDE OF THE ARC IN A BONDED PAIR THAT IS HEADING TOWARD FAILURE. NOTICE THE DAMAGE TO THE CONDUCTOR INSULATION. AS YOU CAN SEE, THE STRESS FORCE IS BEING FOCUSED IN A SMALL AREA THAT IS DETERIORATING WHILE THE REST OF THE PAIR IS IN TACT. THE REASON THE STRESS IS FOCUSED ON A SMALL AREA IS THAT THE BONDING OF THE PAIRS DOES NOT ALLOW THE FORCE TO BE SPREAD OVER THE ENTIRE PAIR. ONCE THE "WEAK SPOT" IS ESTABLISHED, IT WILL ACT AS THE "HINGE" FOR THE CABLE UNTIL IT EVENTUALLY BREAKS.

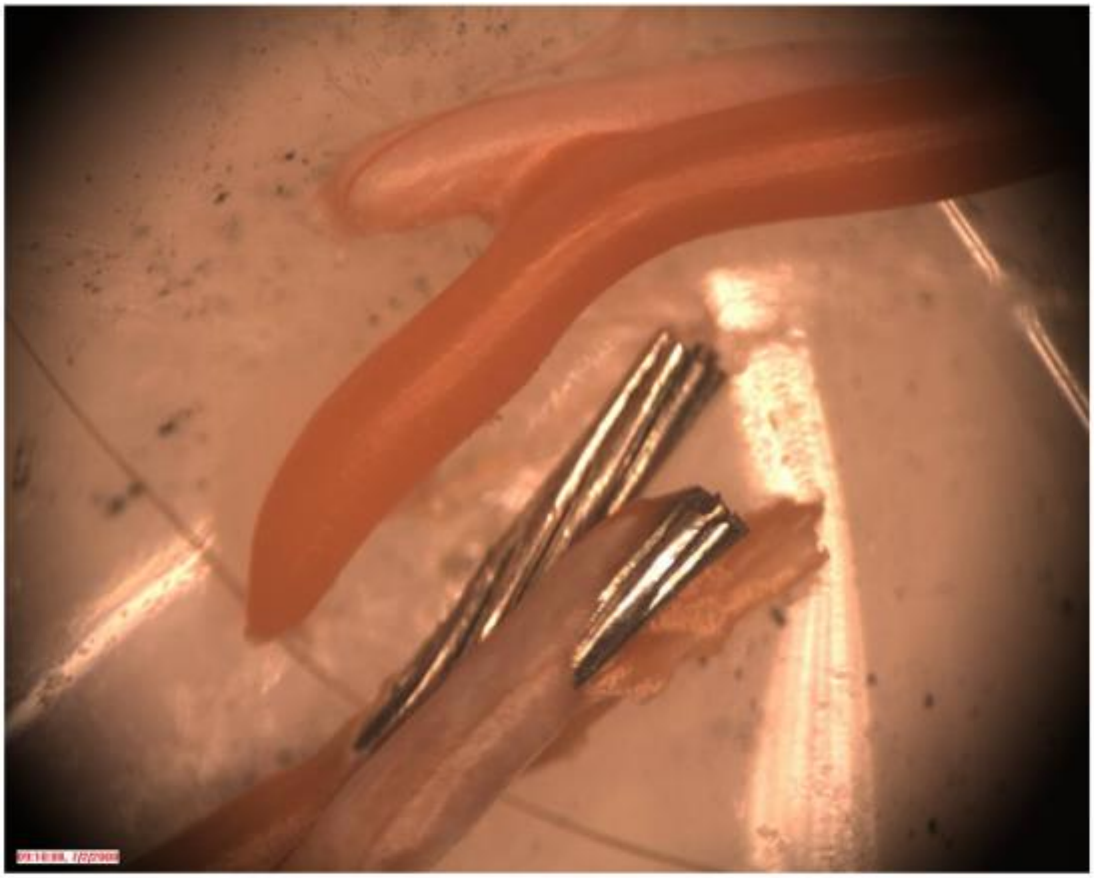


PHOTO 5: ABOVE IS A PICTURE OF A BONDED PAIR THAT WAS PART OF A 4 PAIR "INDUSTRIAL" ETHERNET CABLE. THIS CABLE WAS FLEXED TO THE POINT OF FAILURE USING THE QUABBIN ROLLING BEND FLEX FIXTURE. TEST PARAMETERS FOLLOWED THE SAME TEST SET UP AS USED TO SUCCESSFULLY QUALIFY QUABBIN'S UNBONDED INDUSTRIAL ETHERNET CABLE FOR 10 MILLION FLEX CYCLES. THE BONDED PAIR FAILED AT SOME POINT PRIOR TO 600,000 CYCLES. TO LEARN MORE ABOUT THE QUABBIN INDUSTRIAL ETHERNET CABLE AND THE VIGOROUS TESTING IT GOES THROUGH PLEASE REVIEW THE CORRESPONDING, ROLLING BEND FLEX TEST