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Non-Destructive Testing of Elastomeric Joint Sealants in Construction

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ABSTRACT

Durability of buildings depends on adequate testing and quality assurance programs during construction. Lack of good testing during construction can result in construction defects. In the United States, construction lawsuits have become so costly that construction insurance in now one of the largest costs of doing business for contractors.

This is particularly true in the field of leaking buildings and toxic mold related lawsuits. For that reason, the author has spent the past 7 years in research and development of a comprehensive 100% capable non-destructive method and device for evaluating weather seal sealants. Recently, the author has developed a similar test system that can be used on SSG (Silicone Structurally Glazed) sealants as well.

This paper is focused on the use of non-destructive Quality Assurance systems for sealants in construction that can perform at the rate of 100% if necessary. The current industry standards call for testing of these sealants at the rate of one destructive "pull test" per 1000 lineal feet [305 m]. It is the belief of the author that this standard is woefully short of the needs of the industry. On one project alone, where the author was able to conduct 100% testing, it was discovered that a 0.2% failure rate of the weather seal resulted in over 400 potential leaks on the 227,000 square foot [69,190 m] building, in 35,000 lineal feet [10,668 m] of wall sealant. Statistics related to perfect versus real life application of sealants are also discussed in this paper. ASTM C1521 is cited as a new approach to seal and sealant testing.

KEYWORDS

Sealants, Non-destructive testing, ASTM C1521.

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1 INTRODUCTION

Imagine that you belong to a family that suffers from a genetic flaw that can cause serious health problems. However, your doctor has good news; a test exists to find out if you have any of the health problems associated with the gene. After the test, you will be issued a report of the test results. The problem is that the test is only accurate from between one chance in 4,000, and one chance in 192,000, depending on how you figure the odds.

Now imagine that you are a sealant installer on a construction project that relies on sealants for weatherproofing or safety. A manufacturer's sealant warranty can be obtained if certain project specific tests for substrate compatibility, primer requirements, and field adhesion are performed. An official report follows each test, proving your due diligence. Unfortunately, the odds of finding a seal continuity problem using the industry standard field test is between one in 4,000, and one in 192,000, depending on how you figure the odds. Later, when the building leaks or glass is dislodged, you find yourself in the position of trying to defend your installation with test reports, but you are told that the problems are caused by installation error.

This paper focuses on adhesion field-testing of construction sealants. This is because durable and functional building facades using construction sealants in critical areas require continuous adhesion of the sealant in all joints at all locations.

2 INCONVENIENT STATISTICS

Dr. Joseph Lstiburek,a principle of Building Science Consulting stated: *"It may be possible to install sealant in one joint perfectly –but how about installing sealant perfectly in 10 joints? Now how about 100 joints? Recall, that the joints must be perfectly prepared and installed. How about 1,000 perfect joints? Or 10,000 perfect joints? To put this into perspective, there are more than 1,000 sealant joints per building in most commercial buildings. Many of the joints leak from day one. More joints leak as the building ages."* [Lstiburek 2007].

An associate of the author, a principle of Morrison Hershfield, Ltd., Canada, & Morrison Hershfield Inc., USA, made the following comment when presented with some of the data included in this paper: *"Even with above average workmanship, there will always be a failure rate. Even if sealant joints on any given project are as good as 99.5% successful (an extraordinary achievement in any human endeavour), the remaining 0.5% can cause significant damage. Submarines have bilge pumps to catch the leaks from the 0.5%. There needs to be a second line of defence. Nothing we do is perfect enough to rely on a sealant joint 100% of the time, and in my opinion, this is a foolhardy approach to building design"* [Gallant 2005].

The average commercial building in the United States contains about 35,000 lineal feet [10,668 m] of sealant, or 6.62 miles [10.7 km]. With volumes of face-sealed joints this high, a very small failure rate can result in significant trouble for the building.

In 2002, the American Society for Testing and Materials (ASTM) Committee C24 ("Building Seals and Sealants") adopted a new Field Practice C1521 ("Standard Practice for Evaluating Adhesion of Installed Weatherproofing Sealant Joints") that codified several testing procedures that were already considered industry standards [ASTM 2002]. These procedures include the destructive tail and flap "pull tests", a water immersion procedure, and a non-destructive joint probe procedure that uses a blunt instrument to induce strain to the bond line of the sealant.

The frequency of the destructive pull testing recommended by ASTM is one test per 100 lineal feet [30.48 m] for the first 1000 feet [304.8 m], and one test for every 1000 lineal feet thereafter. This is the recommended test procedure by all of the major sealant manufacturers worldwide. Most manufacturers recommend cutting a 3-inch tab into the sealant bead, and then pulling the tab either to an elongation percentage keyed to the movement capabilities of the particular sealant, or to cohesive failure [Dow Corning 2007].

Assuming that the full 3 inches qualify as the test parameters, the odds of finding continuity problems in the sealant installation is 4,000 to 1. In actuality, the true test is taking place at the interface of the tab to the sealant at the bottom of the tab in perhaps 1.6 mm [1/16"]. This means that the true statistical odds of finding a continuity problem in the sealant joint with this test is closer to approximately 192,000 to 1. Even at the once every 100 feet frequency (impractical, material waste, costly), the odds of finding a problem is 19,200 to 1.

The destructive testing procedure is concerned with, A) the quality of the sealant, and B) whether or not it is able to adhere to the substrate. It is a sealant material Quality Assurance process, not a seal continuity Quality Assurance process.

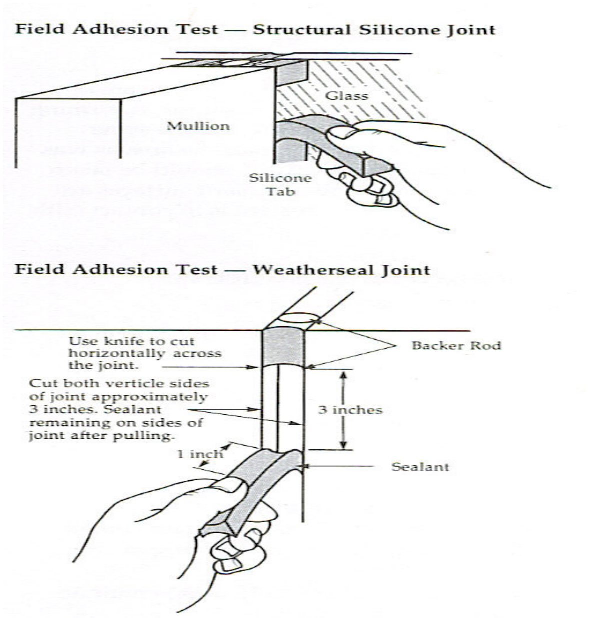

Figure 1. These are depictions of the hand pull test recommended by sealant manufacturers as a standard Quality Assurance program for sealant adhesion for weather seals and SSG. Frequency of the test as recommended by manufacturers varies, but the ASTM recommendation in C1521 is one test per 100 lineal feet [30.5 m] for the first 1000 lineal feet [304.8 m] tested, and one test per 1000 feet thereafter.

3 CONTINUOUS TESTING USING A ROLLING DEVICE – TRUE CONTINUITY QUALITY ASSURANCE

In the ASTM document C1521, a non-destructive procedure is outlined that offers an alternative to the pull test. It suggests that the evaluator subject the sealant bead to pressure with a blunt probe. The objective is to strain the sealant bead inducing stress on the sealant bond line in order to reveal failed or poor adhesion. Put simply, one pokes the sealant with a blunt instrument, with a goal of depressing the bead 50% of its movement capability.

For the reasons discussed above, some Building Enclosure Professionals have been using simple rolling devices such as a window screen roller or a "backer rod placement device" to affect the non-destructive procedure mentioned above. Notably, David Nicastro, principle with Engineering Diagnostics, Inc. and the former chair of ASTM Committee C24, and Patrick Gorman of Gorman

Moisture Control and former Vice Chair of C24 have been using the screen roller approach for a number of years. Currently, C24 has taken under consideration adding rolling devices as a test option. This will be in addition to the “blunt instrument” in the current C1521 Non-Destructive test protocol. The advantage of being able to determine the relative condition of a sealant joint using this approach is obvious – a 100% evaluation of the sealant is now possible.

The problem with any of the un-controlled rolling devices is that they generate non-reproducible subjective test data. For that reason, the author embarked several years ago on a quest for a scientific, objective approach to this idea by creating an adjustable, controlled, and calibratable device.

4 DESCRIPTION OF CONTROLLED CALIBRATED CONSTANT PRESSURE DEVICE

The device is a hand held instrument able to exert pressure in a controlled manner to the sealant joint. Extending from the housing at the front of the device is an armature with a roller at the tip. Behind the armature is a piston charged with compressed gas delivered from a pressurized tank. The amount of pressure behind the piston translates directly into the amount of force that is applied to a surface to which the roller probe is engaged. The amount of gas pressure delivered from the pressurized tank is adjusted with a regulator. Pressure within the device and behind the piston is monitored from a gauge visible on the control box. Within the pressure control box the gas is manipulated in such a way that the pressure is constant within the entire stroke of the piston in the hand held portion of the device. Pressure in the apparatus as derived from the gas source resulting in strain at the probe contact point is maintained if the armature is somewhere within the stroke of the piston. The operator pushing in or pulling away from the joint with the device during operation cannot alter the pressure at the probe contact point. This means that the pressure that the test probe exerts on the sealant remains constant. To maintain constant pressure, the piston must simply be kept within its’ 3-inch [7.6cm] stroke range.

Using this device, accurately applied pressure to the joint is not dependant on adjacent surfaces (as in the case of a backer rod placement style device) or the judgment of the user (as in the case of a screen roller or similar device) when testing. The result is a reproducible and objective evaluation system. The user simply dials up the predetermined pressure for the device to operate on and then lets the device do the rest. A predetermined pressure is set for the specific sealant through calibration of the device.

Figure 2. The picture is a depiction of the pressure-controlled as discussed in this paper.

Calibration of the device is aimed at a 50% elongation of the sealant based on the sealant movement capability, following the guideline for the non-destructive procedure found in ASTM C1521. The calibration numbers used in the field are an average based on the particular sealant and the average joint width on the building. If the test practitioner wishes to, adjustments for joint width changes can be made as often as is necessary, but as a practical matter, using an average pressure is more efficient. When testing organic sealants, it is important to consider temperature changes. Reporting all of the pressures used is important for the archive in order for future reproducibility.

To obtain calibration data, sealant calibration specimens are constructed in three rectangular joint configurations held within a rigid metal grid. Joint configurations are constructed as follows:

- [12.70 mm by 6.35 mm] 500 mil by 250 mils
- [19.05 mm by 9.52 mm] 750 mil by 375 mils
- [25.4 mm by 12.70 mm] 1000 mil by 500 mils

Each specimen is approximately 508 mm (20 inches). Various colors are used in order to factor batching and pigmentation (during the initial 6-month calibration study, pigmentation was discovered to have a slight but detectable effect on sealant movement capability). Movement dial indicators are spaced evenly along the underside of the specimen in order to record the deflection created during a pass of the roller through the sealant on the topside. Differing pressures are used to strain each specimen. A significant number of passes with the roller probe are completed and the deflections recorded. The information is reduced and translated into "target deflections". These target deflections are a percentage of elongation as defined by the specific sealants' movement capability. For example, a target of 50% elongation in a 50% movement capability sealant in a 1 inch (25.4 mm] wide joint would be ¼ inch (6.35 mm) deflection. The result of this process is sealant specific calibrations chart such as is depicted in the example below (Table 1). The table describes the calibration of sealant #1, average Shore "A" Durometer Hardness 28, movement capability ± 50%. Numbers following targets are calibration numbers for the device as a percentage of available force in the control box.

Table 1. Calibration of Sealant #1.

Joint:	Target Deflection:	50%	75%	100%
500 by 250mil (12.70 by 6.35 mm):		40	55	73
750 by 375mil (19.05 by 9.52 mm):		32	51	68
1000 by 500 mil (25.4 by 12.7 mm):		26	43	62

5 STATISTICS FROM FIELD USE

Experience using this device in the field has demonstrated that if at least 5% to 10% of a building is sampled, and the sampling is conducted in a thoughtful scientific manner, the results are usually representative of the entire sealant installation.

For example, on an 11-story building, with 24 grid locations for suspended scaffolding, two grids were sampled. This represented an 8.3% sampling rate. Found were 14 adhesion failures on 1 grid section, and 20 on the other, for an average of 17 failures per grid section. From this sample, it was predicted that 408 failures would be found on the entire building. 427 adhesive failures were uncovered during the ultimate 100% evaluation process. This means that sampling has a solid basis for obtaining a realistic view of the sealant installation on a building.

Figure 3. This is an example of the type of "invisible" seal failure uncovered by using the non-destructive method and device described elsewhere in the paper. Prior to finding this seal breach, the entire sealant bead depicted looked exactly like the area above and below the breach.

What did we learn from sealant testing at the rate of 100%? In the case cited above, the failure rate was a mere 0.2%. Yet it resulted in 427 breaches in the building seal. This demonstrates that a very low failure rate can pose a significant potential problem for a building simply because the volume of sealant used is typically a large number. A 99.8% successful installation is not a bad job, and as Mr. Gallant suggested, a 99.5% rate of success is all one could ever hope for in a "human endeavour".

On one project, a twin 18 story condominium in Long Beach, California, we found a 5.6% failure rate in the Exterior Insulation and Finish System. We started with a 1% sample, and then sampled 5%, then 10%. What was significant is that the failure rate remained constant despite the sample size. This has been a consistent finding on all of the projects where this system has been used. As a result, we recommend that sampling be conducted at a minimum rate of 5% to a maximum of 10% prior to 100% testing as a way of determining the severity of the problem and determining the reasons for the failures. This can also provide the practitioner information for establishing a protocol for using the test system as a repair program. The failed samples should be removed for analysis. This will reveal the reasons for the failure, most often from contaminated substrates, but in some cases, laboratory analysis is appropriate. We have also found that when full scale testing is undertaken, it is often cost effective to coordinate the testing with a contractor able to implement repairs. After the repairs are made, a 10% re-sample is useful in confirming the success of the test and repair program.

The information in Table 1 provides basic statistics obtained during a 100% sealant evaluation of the newly constructed building (specimen A) using the pressure controlled and calibrated device and used in accordance with the principles of the non-destructive test protocol outlined in ASTM C1521 [ASTM 2002a].

Table 2. Statistics Generated from Sealant Testing (Specimen A).

Number of Lineal Feet of Sealant:	35,000 feet [10,668m]
Number of Adhesive Failures:	427
Average Length of Failure:	two inches [50.8mm]
Failure Rate in Lineal feet:	one in 82 feet [25m]
Total Lineal feet of Sealant Failure:	71 feet [21.6m]
Percentage Rate of Sealant Failure:	**.2% Failure**
Percentage Rate of Sealant Success:	**99.8% Success**

The author is currently involved in an adaptation of the non-destructive testing technology described in this paper for use in evaluating Silicone Structural Glazing (SSG). This new test system is designed for non-compressible sealant joints and gaskets.

6 CONCLUSIONS

The future of field-testing of sealants should therefore necessarily include non-destructive procedures that have the ability to test 100% of sealant joints. Continuous testing using rolling devices have been demonstrated to be a good choice. The program should have a goal of finding the seal breaches and simultaneously repairing them immediately. This approach to building seal verification has the potential to save many dollars in building maintenance, litigation, health care costs, insurance, and owner borne construction costs, to name a few. In the case of SSG applications, life safety issues are involved. Improved testing technology can provide all concerned with a new level of confidence that durable building seals and structural silicone glazing adhesives can be realized. The question now is not whether we have methods and technology to accomplish durability of construction, the question is whether we have the will to use it.

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