Monitoring Performance of EIFS Clad Dwellings

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ABSTRACT

Exterior insulation and finish systems (EIFS) are popular exterior wall cladding systems used on residential as well as commercial construction. In 1995, there were reports of moisture intrusion in residential dwellings clad with barrier type EIFS along coastal North Carolina. Subsequently, there have been reports of water intrusion in homes clad with other types of claddings as well. Inspections and further reports have revealed moisture was entering primarily through and around building envelope components, such as windows, flashings, etc., which indicates that these occurrences are not related to a type of cladding.

Performance of a home as it relates to weather resistance is typically evaluated via an inspection and possibly, in the case of barrier type cladding systems, in conjunction with commercially available resistance probe-type meters capable of measuring moisture contents in the underlying sheathing material or capacitance-type meters, which may be used to locate general areas containing moisture. An alternative means, which is the basis for this paper, is to collect such data using a data logger or acquisition system. This alternative means of data collection can be adapted for use on homes clad with barrier as well as drainage-type cladding systems. It is a practical way to collect numerous data points over an extended time period and provides a potential means to assist with assessment of performance. Additionally, data acquisition systems, unlike probe-type meters, do not require intrusive investigation and, unlike capacitance type meters, can locate, as well as potentially quantify, the level of moisture in the underlying substrate. This paper will discuss the various aspects and consideration of using data loggers and will provide case studies of projects currently being monitored.

INTRODUCTION

Exterior insulation and finish systems (EIFS) are exterior veneer or wall cladding systems that have been widely used in the United States for more than three decades. They are the most common wall cladding system used in the commercial construction market and also have widespread use in residential construction. Typical components of an EIFS include an insulation board that is covered with an external coating system consisting of a reinforced base coat followed by a finish coat that provides the final appearance. EIFS function as a barrier type system and, in conjunction with other building envelope components, keep moisture from bypassing the external surfaces of the envelope. The systems are applied to substrates, such as masonry, or on framed construction with wood-based as well as gypsum sheathing.

In 1995, there were reports of moisture intrusion in barrier EIFS clad homes along coastal North Carolina (Donovan et al. 1999). Reports of moisture entry have also become evident in other areas of the country and have affected homes with other claddings as well. It has been documented by the authors as well as other third parties that much of the moisture intrusion is attributable to changes in building materials and practices that have occurred in residential construction, which has resulted in leakage through and around other components in the building envelope, such as windows, flashings, etc. (Holladay and Vara 2000; Halverson et al. 2000; Egan 2000; Wilkes 2000; Alexander 1998; Brooks 2000). The resulting leakage

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has caused some homes, regardless of the cladding type, to be in need of remediation. The repairs or remediation techniques typically consist of rectifying the source of the moisture entry, replacement (if necessary) of underlying or adjacent materials, followed by localized replacement of the cladding.

Unless there is obvious damage or a known source, it is sometimes difficult to visually determine if a structure has been subject to moisture entry. Structures can be intrusively investigated to make this determination; however, this may be undesirable for a variety of reasons, such as cost and disruptiveness to occupants, and the usefulness of the information is generally limited to areas that are exposed during the investigation. An alternative to destructive investigation is the use of a scanning or noninvasive-type instrument, such as a capacitance-type meter that requires the user to move the handheld equipment over the surface of the cladding and uses outgoing and incoming electronic signals to record different levels of penetration through the materials. It is capable only of locating general areas of potential moisture and often provides relative, rather than quantitative, data. As such, it is subject to interpretation and results in the need for additional investigation if areas of moisture appear evident. Additionally, this method does not identify the wall component that contains the moisture. These devices can also provide false positive readings due to physical properties, locations, etc., of other materials and products in the wall assembly, such as heat ducts, metallic pipes, etc.

Electrical probe or resistance-type meters are another means to determine if moisture exists in underlying substrate materials. For this method, the user penetrates the cladding with a two-pronged pin that enters the surface of the underlying substrate material. It functions on the principle of electrical resistance and provides direct percent moisture content readings in common underlying substrate materials. Although this is one of the most common evaluation methods in use, it does create small, intrusive probe holes in the cladding that must be repaired. Also, results obtained from probe-type instruments can be skewed by items such as recent precipitation, surface moisture, and depth of probes in the substrate, etc. Finally, some interpretation may be needed for assemblies that incorporate a secondary weather barrier over the underlying substrate since it may be difficult to determine the location of moisture. Additionally, all of the above evaluation methods generally provide a snapshot view of building performance rather than a view over an extended time period.

EXPERIMENTAL DESIGN

The key objective was to provide an alternative means to monitor building performance. Specifically, it was desired to find a nonintrusive means to record data that would enable evaluation of underlying substrate conditions over an extended time period without having to continually visit the project. A standardized means to accomplish this objective was not found to be available. Consequently, the design, equipment selection, etc., were developed by the authors and used with EIFS; however, alternative claddings could likely be utilized and adopted for such a study.

A four-channel outdoor/industrial logger was selected as the means to record the data. Although other types of data acquisition equipment or loggers are likely suitable, the model used was selected for a variety of reasons, such as availability, cost, multiple channels, means of data retrieval, battery operation, operating ranges, ease, and versatility of programming, etc.

The logger functions by sending a pulse from the channel via a dedicated lead or cable that also contains a “switch.” The switch consists of two leads or poles a specific distance apart and mounted with stainless steel screws to the underlying substrate in both barrier and drainage-type assemblies (Figure 1). The pulse is returned through the switch back to the logger, which records voltage drops if there is moisture in the underlying substrate at that location. The voltage readings can be

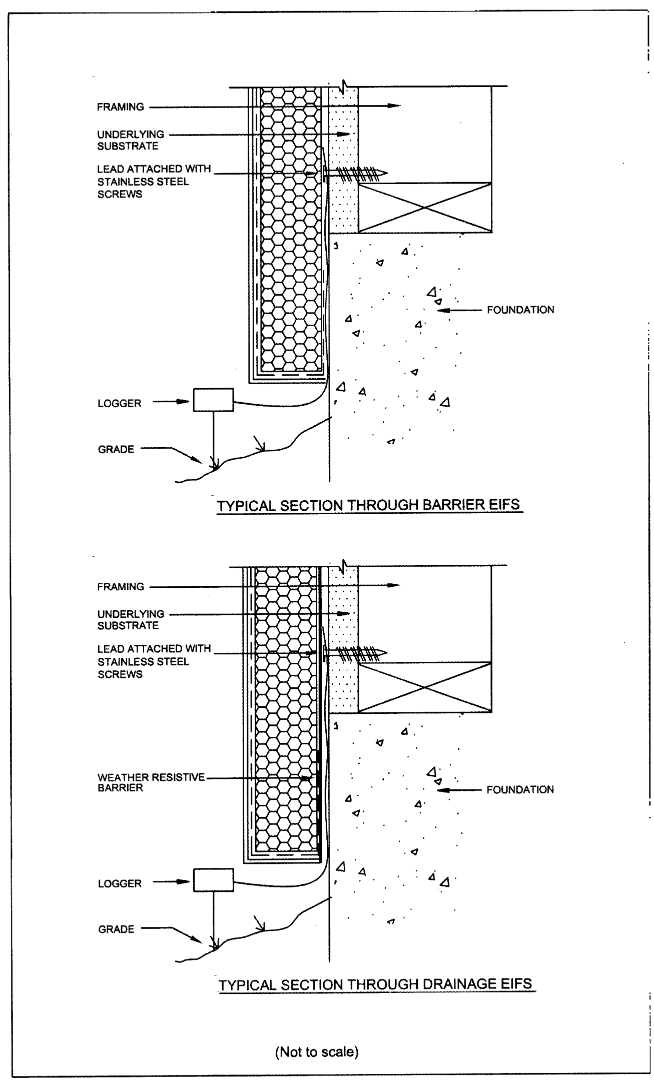

Figure 1 *Typical lead/logger locations.*

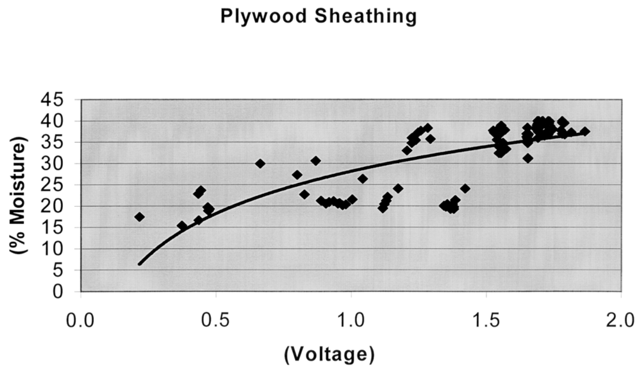

Figure 2 *Voltage to percent moisture correlation.*

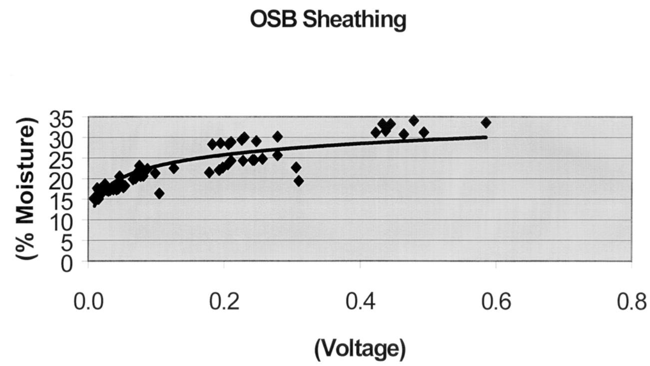

Figure 3 *Voltage to percent moisture correlation.*

converted to percent moisture contents based on interpolation of trend lines developed through independent laboratory testing. The testing was conducted (Kessler and Woods 2000) to correlate voltage drops to percent moisture contents in common wood-based sheathing substrate materials (Figures 2 and 3). Although equipment capable of providing direct percent moisture contents in common substrate materials would be advantageous, such equipment was not available. Consequently, voltage to percent moisture correlations were established through independent laboratory testing.

The leads are typically located at select areas of the building that have been subject to moisture entry in the past, such as below windows, flashings, etc. Additionally, one or more leads should also be used in a weather-protected area that is not anticipated to be subject to moisture. Essentially, this serves as a control to document and provide a basis to compare the normal moisture content of the underlying substrate to other areas of the structure. The loggers, which are relatively small units (140 mm × 140 mm), are typically mounted on a small post set in the ground and can be easily hidden behind landscaping.

For this study, the data acquisition equipment was programmed to record daily readings at eight-hour intervals (midnight, 8 a.m., and 4 p.m.) in an effort to gain numerous data points, see fluctuations over time, as well as provide an extended picture of building performance. Readings are periodically downloaded from the data loggers via a shuttle data transporter, which provides a means to transport data recorded from the project to a computer.

RESULTS AND DISCUSSION

The following summarizes two studies underway that are monitoring the performance of EIFS clad homes using the data acquisition equipment. The findings that follow each study are based on recorded voltages converted to percent moisture based on the type of wood-based sheathing and trend lines established through the previously referenced independent laboratory testing. Maximum 20% moisture content in the underlying wood-based sheathing substrate is considered an acceptable moisture level since untreated wood will have indefinitely long service without decay if the moisture content remains below 20% (American Institute of Timber Construction 1994). Should the moisture content exceed 20%, further investigation should be undertaken to determine the cause of such readings. Once the cause has been determined, appropriate actions should be taken, recognizing that somewhat higher moisture contents may not result in reduced service life.

Study #1. Southern Pines, North Carolina

Background Information. This is a one-story wood-frame home in the south-central region of North Carolina with wood-based (oriented strand board) sheathing that was originally clad in part with a barrier-type EIFS. An independent third party inspection of the home's exterior was performed and included moisture testing with a scanning as well as resistance probe-type meter. Although high moisture readings were not evident, some soft areas were noted in the underlying wood-based sheathing substrate below two windows on the front (west) elevation. It appeared the underlying substrate was most likely damaged as a result of moisture entering through the window units. Consequently, it was determined remedial repairs would be necessary to address the sources of moisture entry as well as damage, if any, to the substrate material. Localized installation of the EIFS follows the remedial work.

Remediation. In May 2000, portions of the barrier EIFS and areas of moisture-damaged, wood-based sheathing substrate around the two front windows were removed. A new wood-based substrate consisting of oriented strand board (OSB) sheathing was installed in the damaged areas. As the moisture remediation measure, copper pan flashings were installed below both windows to collect as well as redirect incidental moisture from these locations. The data logger leads were placed below both windows on the front (west) elevation since these were the areas repaired and the objective was to monitor the effectiveness of the repairs. Lead wires for logger #1 were installed over the substrate below the left window, including areas where prior moisture was evident. Lead wires for logger #2 were installed below and around the right-side window. One lead wire from logger #2 was installed as a control and the remaining three wires were installed in areas below the window where the substrate was damaged due to excessive moisture. A weather-resistive barrier along with a drainage-type EIFS were then installed over the substrate only in localized areas where the barrier EIFS had been removed.

Findings. For logger #1, data were recorded from mid-May 2000 through mid-February 2001. All four channels showed essentially flat line graphs, which translates to little or no change in moisture content over the time period. The maximum voltage drop was less than 0.05 volts, which, based on the trendlines for OSB sheathing (Figure 3), correlates to percent moisture contents that are significantly less than 20% and, consequently, not a concern for wood decay.

As with logger #1, all but channel 4 showed essentially flat line graphs, which indicates little or no change in moisture content from the period of mid-May 2000 through early February 2001. The maximum voltage drop was significantly less than 0.05 volts, which indicates the moisture content of the sheathing was well below 20%, which once again is not a concern for wood decay. With respect to channel 4, this was the control located in a protected area in the field of the wall away from penetrations, etc. This channel exhibited consistently high voltage readings even though prior moisture was not previously noted at this location when the EIFS in this area was removed during remediation. Subsequent inspections, which included an intrusive investigation with a probe-type resistance meter, did not reveal moisture content in excess of 20% nor areas of possible moisture entry. Possible explanations for the readings from channel 4 include inadvertent damage to the cable by a staple or fastener during the repair process or logger malfunction.

Figure 4 *Residence #2, Bricktown, N.J., elevation with logger locations.*

Study #2. Bricktown, New Jersey Residence

Background Information. In the spring of 2000, construction started on a new, three-story wood-frame home with wood-based (plywood) sheathing to be clad with a drainage type EIFS (Figure 4). The home is located on an inlet along the east coast of New Jersey. The data logger system leads were installed over the substrate in July of 2000. Figures 5 and 6 show approximate locations of the data logger leads. All leads except for #1 of logger 1 were located at window mullions or jamb/sill intersections since these were areas of windows that have been subject to water infiltration in the past. Loggers were installed only on this elevation (west) due to logistics of the project. The weather-resistive barrier was installed in August 2000, followed by the drainage type EIFS in the fall of 2000.

Findings. Figures 7 through 9 are graphs of data from logger 1. For logger #1, data have been recorded from mid-July 2000 through early February 2001. After the early part of September, the three channels in use showed essentially flat line graphs, which indicates little or no change in moisture content of the underlying substrate. The maximum voltage drop was less than 0.05 volts, which, based on the trendlines

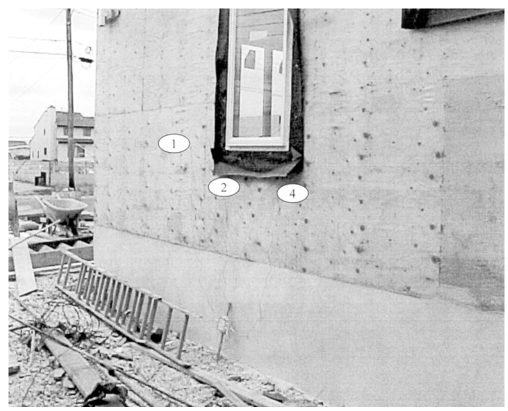

Figure 5 *Residence #2, Bricktown, N.J., lead wire locations.*

Figure 6 *Residence #2, Bricktown, N.J., lead wire locations.*

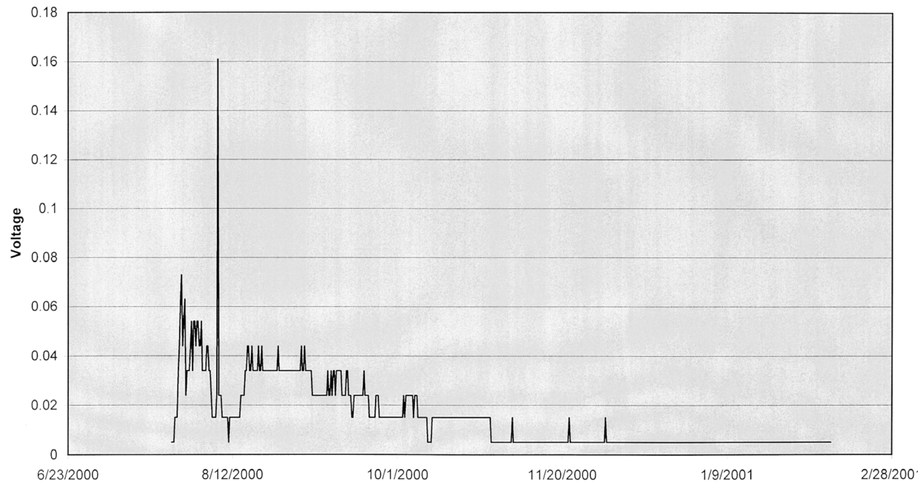

Figure 7 *Residence #2, Bricktown, N.J., Logger 1—Channel 1.*

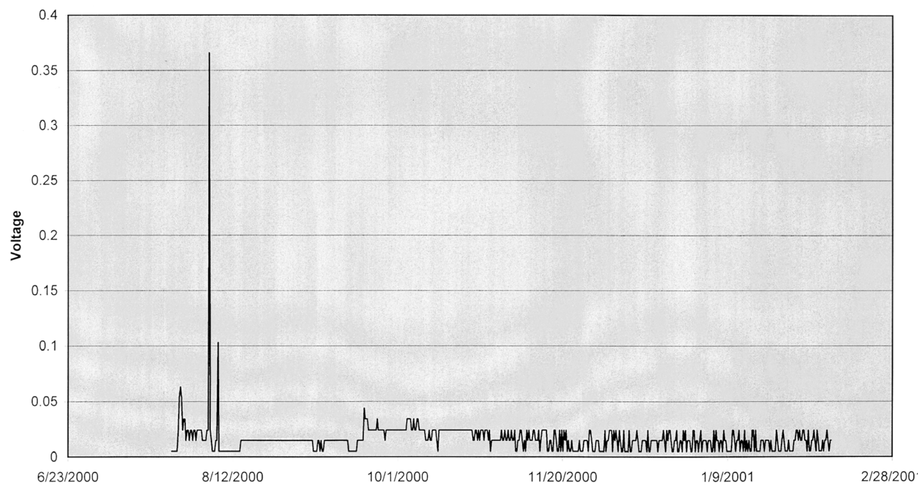

Figure 8 *Residence #2, Bricktown, N.J., Logger 1—Channel 2.*

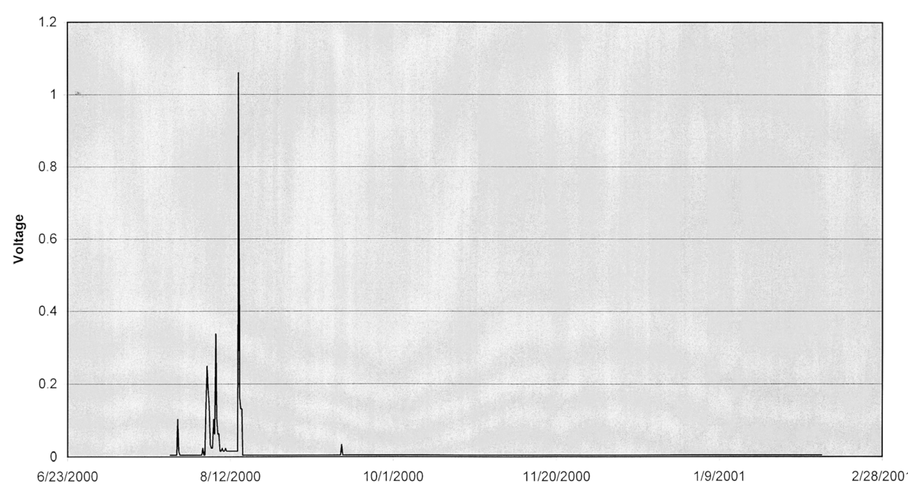

Figure 9 *Residence #2, Bricktown, N.J., Logger 1—Channel 3.*

for plywood sheathing (Figure 2), correlates to percent moisture contents that are significantly less than 20%, which is not a concern for wood decay. Channel 4 of logger #1 was not needed and, consequently, not used. With respect to the spikes on the graph that occurred in August 2000, these are attributable to a time of heavy rainfall when the loggers were directly exposed to the weather prior to the installation of the weather barrier, cladding, flashings, sealants, etc. Although high moisture readings were evident at the time, an item to note is the drop in moisture content after the installation of the cladding, which indicates drying of the underlying substrate.

For logger #2, all three channels in use after the early part of September showed essentially flat line graphs, which indicates little or no change in moisture content through early February 2001. The maximum voltage drop was significantly less than 0.05 volts, which indicated the moisture content of the sheathing was well below 20% and, once again, not a concern for wood decay. As with logger #1, the spikes on the graph through the end of August 2000 are attributable to the time the loggers were exposed to the weather prior to installation of the cladding, flashings, sealants, etc. Due to an inoperative wire, channel 3 of logger #2 was not utilized.

CONCLUSIONS

Data loggers or acquisition systems, such as the ones used in these studies, are an alternative means to gather data and monitor building performance. Advantages over some current methods include the ability to gather numerous data points over an extended period of time without continuous site visits, and it is a nonintrusive method when installed prior to the cladding. Although it may not be practical to monitor conditions of the entire structure, an acquisition system can be set up in specific areas such as at windows, flashings, etc., where moisture entry has occurred in the past. Interpreting the data can provide an indication of overall building performance, insight as to whether excess moisture exists in areas such as underlying substrate materials, as well as show the effect of seasonal differences, changes in weather, etc., on moisture content of the underlying substrate. These data can be used in a number of ways, including verification of system concept performance or to monitor performance of a specific structure. Additionally, such systems can be adapted to monitor a variety of cladding systems.

As far as accuracy of the information is concerned, numerous samples and conditions were used to determine the trend lines generated from the independent laboratory testing. Additional work could be performed to further validate the results as well as those of other common substrate materials, such as gypsum sheathing, cement boards, etc. Although the main concern of this study is moisture content greater than 20%, the sensitivity of the meters should be enhanced to track lower levels. As far as issues that were encountered or might be anticipated, one key item is the need to coordinate the logger installation with the project completion schedule since the acquisition equipment is intended to be installed after the substrate but prior to the cladding system. Additionally, some minor issues were encountered while attempting to record data. For example, one channel was found to be inoperable at the time of installation and another was providing readings deemed to be erroneous. Obviously, ensuring that wire cables and connections behind the cladding are functioning properly is a key due to difficulty in accessing the cables and leads after the cladding is installed.

With respect to performance of EIFS clad dwellings, the information obtained to date is an additional means to demonstrate that homes clad with drainage EIFS or with a barrier EIFS that has been properly remediated can protect the underlying substrate from excess moisture. Although this study is limited in scope, it provides supplemental support to existing testing as well as successful projects that show the viability of this cladding system.

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