Hidden from View: Investigating Masonry Veneer Anchorage

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ABSTRACT

Deficiencies in masonry veneer attachment can result in sudden or premature failures. Such failures can result in safety hazards due to falling veneer, especially in areas where the veneer is overhead adjacent to common walkways or locations of ingress/egress. However, the veneer attachment is not typically visible and; therefore, attachment issues, whether they are from defects in the original veneer installation or related to deterioration over time, may not be readily apparent until a failure has occurred. This paper addresses anchored masonry veneers, such as brick and natural stone, and discusses investigation methods varying from non-destructive evaluation, to minimally-destructive observation, to localized veneer removal. Non-destructive determination of anchorage locations can be used to identify as-built deficiencies and to highlight areas for further (destructive) testing and detailed observation. Examples of such non-destructive wall tie location surveys are presented, and the evaluation of deteriorated anchorages (i.e., wall tie corrosion) is also discussed.

ANCHORED MASONRY VENEER

Masonry veneer systems typically consist of a single layer of brick, concrete, artificial stone, or natural stone units attached to the walls and other elements of a structure. Modern masonry veneer systems are most commonly attached with metal veneer anchors (wall ties) or adhered with mortar to the underlying structure.

The discussion presented herein focuses on the attachment of anchored masonry veneer systems used in modern cavity wall construction. The typical components of a cavity wall are shown in Figure 1, and consist of: cladding (e.g., masonry veneer), air space (drainage cavity), air and moisture barrier (drainage plane), exterior sheathing, framing and insulation, and interior wall finishes.

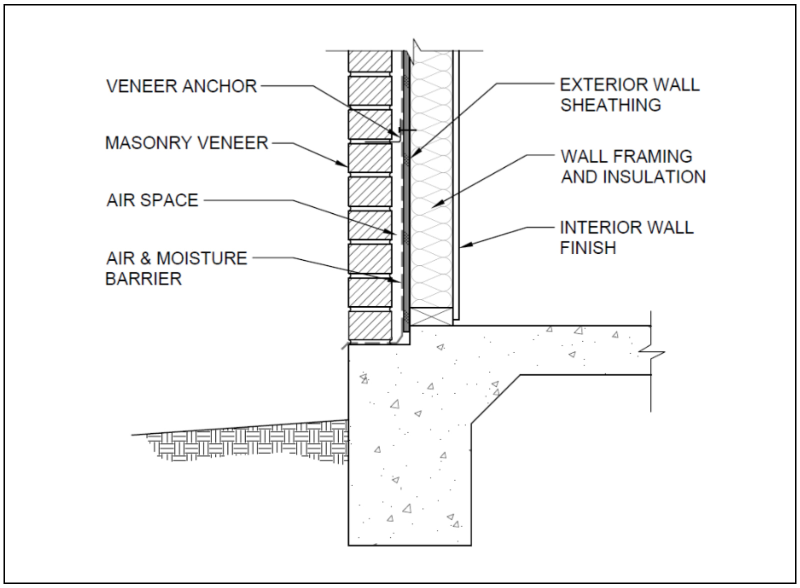
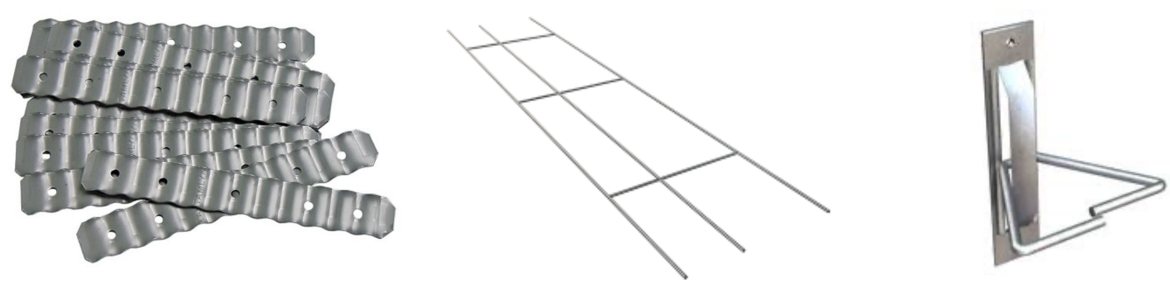


Figure 1: Typical Cavity Wall Components

Masonry veneers utilized in cavity wall construction must be supported by, and mechanically attached to, the building structural elements in order to transmit vertical loads from the weight of the veneer and lateral loads from forces applied to the veneer (e.g., wind and seismic loads) to the underlying structure.

Lateral loads on masonry veneer systems utilized in cavity wall construction are transmitted to the underlying structure primarily through the masonry veneer anchors. These anchors may consist of a single element (i.e., “box” ties, "Z" ties, and corrugated ties) commonly referred to as "unit ties", continuous horizontal joint reinforcement, and adjustable ties with multiple components. There are a multitude of veneer anchor types for various applications. Common examples of veneer anchors are shown in Figure 2 for illustrative purposes.



Corrugated Ties | Joint Reinforcement | Adjustable Tie

Figure 2: Common Masonry Veneer Anchors.

For a veneer anchor system to properly serve its intended function, the anchors must be appropriate for the particular application, properly distributed within the veneer system, correctly attached to the veneer and the underlying supporting structural system, and in sound condition. The veneer anchor system must also have sufficient stiffness to transfer lateral loads with minimal deformations, to limit deflection and associated damage to the veneer.

A detailed discussion of building code requirements for masonry veneer installation is beyond the scope of this document; however, such requirements can be found in contemporary building codes, such as the International Building Code (ICC 2017) and The Masonry Society publication *Building Code Requirements and Specifications for Masonry Structures* (TMS 402/602-16) (TMS 2016). Any veneer system evaluation should consider the relevant portions of these documents.

NON-DESTRUCTIVE VENEER ANCHOR SURVEYS

Background. Non-destructive surveys can be used to determine the locations of veneer anchors within a masonry veneer system with a high degree of accuracy. The data obtained in the non-destructive surveys provides information regarding the locations of individual veneer anchors, which can then be used to assess the distribution/spacing of the anchors. This survey data can be compared to project and building code requirements to assess the adequacy of the anchor distribution, and can facilitate the identification of potential safety issues due to a lack of proper veneer anchorage. Such surveys can also be used to identify locations where destructive testing can be performed to gather additional or more specific information regarding the anchor installation or the condition of the anchorages.

Survey Methodology. The non-destructive veneer anchor survey process is similar to methodologies utilized to determine the locations of reinforcing bars in concrete. The surveys discussed herein were performed using an Imp Wall-Tie Locator, manufactured by Protovale®; however, various similar devices are available. The Imp Wall-Tie Locator uses magnetic pulse induction from a wire coil to detect metal veneer anchors embedded in the mortar beds of the veneer. The device includes a hand-held search coil that attaches to a control unit carried by the operator (Figure 3). The sensitivity of the device can be adjusted on the control unit to detect anchors at a range of depths. The operator receives an auditory alert when the presence of a veneer anchor (or other metallic object) is detected.

The survey methodology consists of selecting survey areas at accessible portions of the veneer, determining the veneer anchor locations by traversing all mortar joints within the survey area with the search coil, and marking the locations of detected anchors with tape, chalk, or other means (Figure 4 and Figure 5). The size of each survey area, the number of veneer anchors detected, and the locations of the detected veneer anchors is then documented.

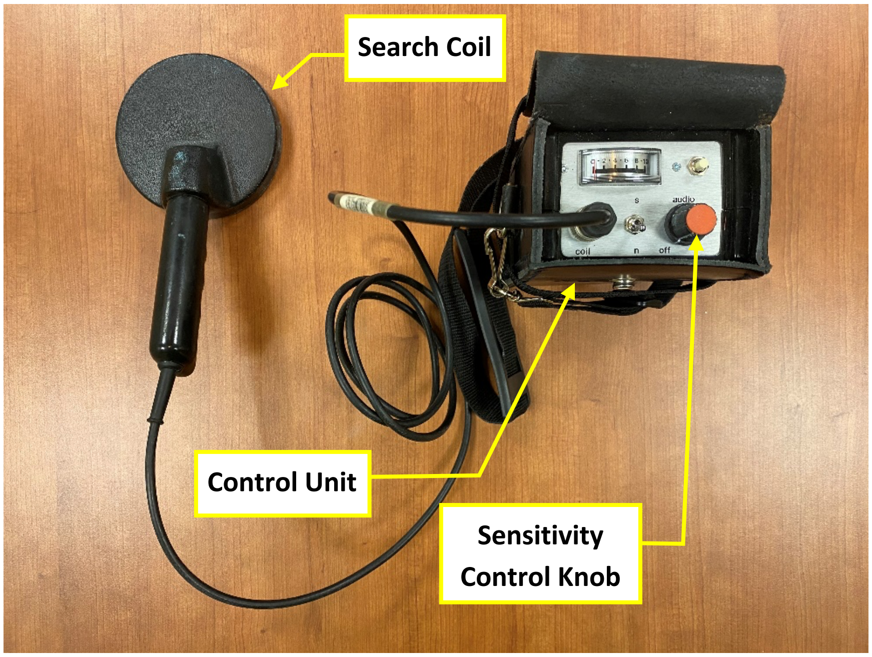


Figure 3: Overview of the Imp Wall-Tie Locator.

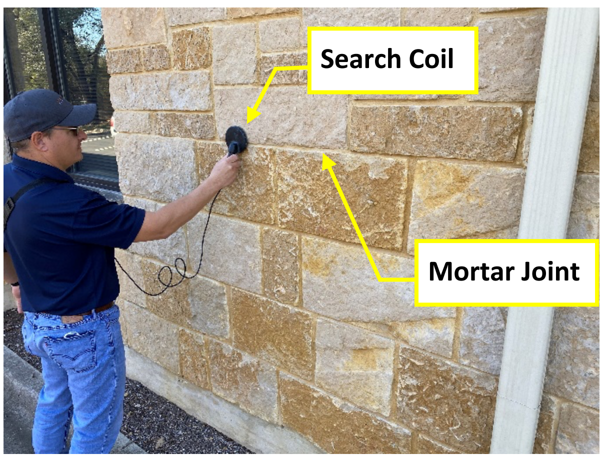


Figure 4: Overview of non-destructive survey in progress.

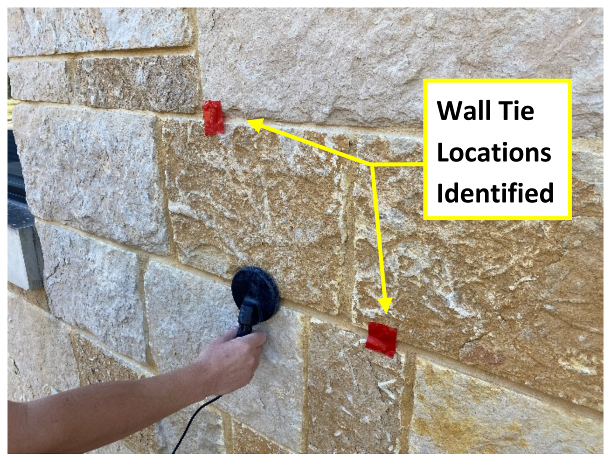


Figure 5: Wall tie locations marked within survey area.

In the authors' experience, traversing the mortar joints with the Wall-Tie Locator set to a higher sensitivity provides a good initial indication of the general location of the veneer anchors; more precise locations for the anchors can then be determined by reducing the sensitivity of the instrument. The authors find that heavy-duty tape (duct tape, or similar) applied to the veneer is an effective method for recording the locations of the detected veneer anchors, because the tape does not mar or stain the veneer surface and the tape locations can be moved to accommodate the increased precision of anchor locations during the survey. Additionally, various colors of tape are available to allow for good contrast/visibility in photographic documentation, and removal of the tape without causing residual surface damage is easily accomplished after completion of the survey.

Once a survey has been performed, the anchor distribution can be analyzed considering the overall density of anchors (i.e., wall area per anchor) and the distribution/spacing of the anchors within the surveyed areas. Some areas of a veneer system may exhibit significantly higher or lower anchor densities. For example, the authors have found that anchor density is commonly higher directly above steel lintels spanning doors and windows, while adjacent areas in the field of the wall will commonly have lower anchorage density, and some areas may have little to no veneer anchorage (Figures 6 and 7). In such cases, analysis of the veneer anchorage may be best performed by considering the density of anchorage directly above the openings separately from the anchorage at the remainder (field) of the wall area.

Figure 6: Overview of typical survey area at stone masonry veneer.

Figure 7: Overview of typical survey area at stone masonry veneer.

The authors have achieved a high degree of accuracy in determining the locations of veneer anchors via non-destructive surveys for cavity wall systems anchored to wood framing, steel framing, and concrete masonry superstructures. Accuracy of the survey method was verified by performing non-destructive veneer anchor surveys at areas where some destructive testing was scheduled to take place. Therefore, the locations of detected anchors could be compared with conditions actually observed within the wall cavity.

In one such example of survey verification, the authors detected 413 suspected anchors. Seven (1.7%) of the suspected anchors were metallic debris (such as soda cans) behind the stone veneer, five (1.2%) were anchors that were not fully engaged with the veneer, and three (0.7%) were false positives where no anchor was present at the suspected location. Therefore, approximately 96.4% of the suspected locations of fully engaged veneer anchors were confirmed by destructive testing. However, the authors observed twelve fully engaged anchors at areas of stone veneer removal that were not individually located by the veneer anchor surveys. Of these anchors that were not detected, four were located in close proximity to other anchors or metal objects, and therefore were not individually detected. Therefore, 398 of the 410 (97.1%) fully engaged anchors that existed within the areas evaluated were detected in the surveys.

At another property, veneer anchor surveys were performed at multiple buildings, including areas with both stone veneer and brick veneer, and the findings were verified with follow-up destructive testing. For these surveys, the authors achieved an accuracy of approximately 95.7% (i.e., approximately 95.7% of the veneer anchors observed during destructive testing were identified by non-destructive surveys prior to veneer removal).

The surveys at this property also indicated a distinct difference in the anchor densities based on veneer type: less than 60% of the required anchors were installed at the surveyed stone veneer, while approximately 94% of the required anchors were installed at the surveyed brick veneer. The anchors for the brick veneer were also more evenly distributed, and more closely complied with code-prescribed spacing requirements (Figures 8 and 9).

Figure 8: Overview of typical survey area at brick masonry veneer (anchors denoted with chalk "x" markings).

Figure 9: Overview of typical survey area at stone masonry veneer.

The coursing of stone veneer is somewhat irregular when compared to the consistent coursing typical of brick veneer. This is particularly true when considering stone veneer with a rubble masonry configuration. Irregular coursing makes it inherently more difficult to install veneer anchors at regular intervals, and this may affect the density of the installed anchors. This is an example of an issue that, while not visibly apparent at the face of a veneer wall, can be studied using non-destructive veneer anchor surveys.

In some cases, veneer anchors that are not properly embedded within the veneer (Figure 10) can be identified based on the difference in auditory feedback on different sensitivity settings.

Figure 10: Veneer anchor that was detected during a survey but not anchored into the veneer.

Because the Wall-Tie Locator detects the presence of metal within the wall/veneer system, care must be taken in adjusting the sensitivity of the Wall-Tie Locator when performing surveys over steel framing, due to the potential for interference caused by the framing system. Other factors that the authors have found to contribute to interference during the veneer anchor surveys include metallic appurtenances (such as gutter downspouts, metallic lights, metal fences, metal flashings/accessories, and utility penetrations), metal lath lapped behind the veneer (such as from an adjacent stucco or adhered veneer system), foil-faced sheathing, and metallic debris within the wall cavity. Care should be taken to avoid potential sources of interference and to eliminate or significantly mitigate the effect of such interference on the results of the survey. If erratic soundings by the Wall-Tie Locator are prevalent, destructive testing may be prudent to determine the cause of the interference and to develop strategies to minimize its effect on the accuracy of the veneer anchor surveys.

DESTRUCTIVE VENEER ANCHOR OBSERVATION

Determining veneer anchor locations non-destructively provides valuable information regarding the location of the veneer anchors, but does not establish the condition of the veneer anchor (e.g. if it is corroded/deteriorated) or the adequacy of the veneer anchor attachment to the structure or veneer. However, the ability to accurately determine the locations of the veneer anchors in a non-destructive manner can facilitate a focused approach to destructive testing, thereby limiting the invasiveness of the veneer evaluation.

The distribution of veneer anchors detected by non-destructive surveys can be used to identify irregular patterns of anchor installation and anchors that are likely not properly attached to the underlying framing members. Detection of veneer anchors that are randomly placed and not aligned vertically at regular intervals, provides an indication that a portion of the veneer anchors are not installed into framing members and are instead connected only to the sheathing. Placement of veneer anchors into sheathing (rather than framing) reduces the withdrawal resistance of the veneer anchor. Therefore, although the veneer anchor surveys verify the existence of these anchors and the anchors are engaged with the veneer, the anchors may be providing insufficient lateral support for the veneer.

Minimally-Invasive Destructive Testing. Minimally-invasive testing to visually assess veneer anchor conditions can be performed with a borescope or by removing individual masonry units. Non-destructive surveys (such as those discussed in the preceding section) can help to determine the locations for minimally-invasive testing, in conjunction with the specific requirements of the project. In some cases, locations targeted for destructive testing may be informed by the pattern/distribution of the veneer anchors detected in the survey and/or by conditions on the surface of the veneer (such as cracking, spalling, or discoloration) that indicate the potential for an underlying issue. Destructive testing locations may also be based on a random sampling chosen to assess the general condition of the veneer attachment. The specific testing protocol utilized should be determined based on the unique characteristics of a given project.

The borescope destructive testing method involves drilling a hole into the mortar joint or masonry unit at the area(s) to be evaluated and inserting a scope into the drilled hole in order to observe the conditions within the veneer cavity. Evaluations with a borescope are generally limited to a visual assessment. A camera attachment can be used on the scope to document the conditions observed (Figure 11).

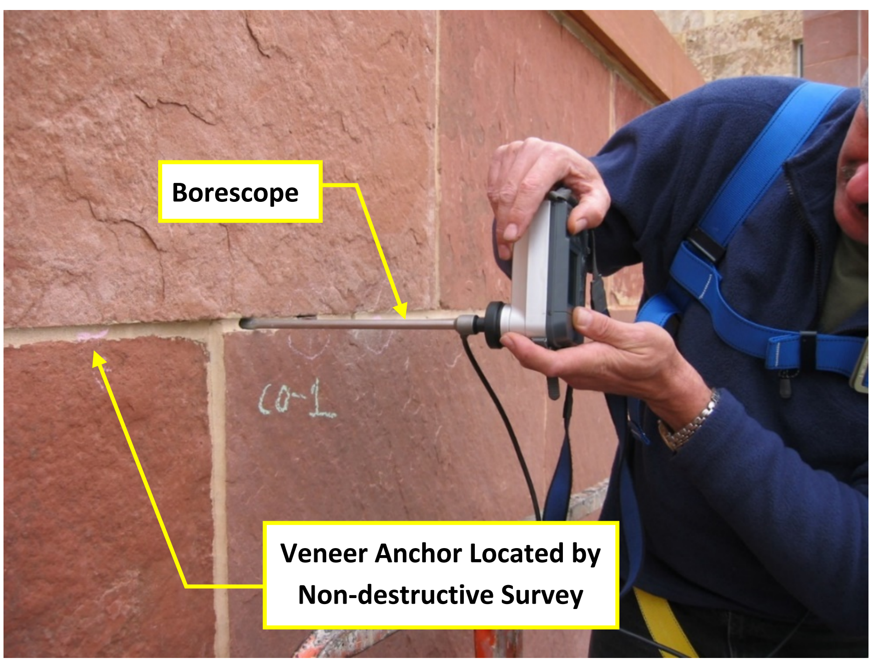


Figure 11: Evaluation of veneer anchor with borescope.

Removal of individual masonry units involves saw-cutting or chipping away the mortar around the perimeter of the masonry unit (or units) to facilitate removal. Removal of individual masonry units may provide better visibility of the veneer anchorage conditions, when compared to the borescope method. Additionally, removal of individual masonry units may facilitate the evaluation of the veneer anchor attachment to the structure and veneer, such as by measuring the depth of anchor embedment into the veneer mortar joints, determining the location of attachment of the veneer anchor fastener to the structure (i.e., determining if the anchor is correctly attached to the structural framing), and/or determining the strength of the veneer anchor attachment to the structure such as by pull testing.

Figure 12 shows an example of an anchor exposed with limited veneer removal. This revealed that the stainless steel anchor had been installed with a mild steel fastener (which had started to corrode) and that the installation was such that the anchor was restraining further vertical movement of the veneer.

Figure 12. Tie installed such that it restrains vertical movement of the veneer.

Large-Scale Veneer Removal. Larger-scale removal of a veneer system may be warranted depending on the specific parameters of a given veneer system evaluation. Non-destructive veneer anchor surveys may provide minimal additional information in the case of larger-scale veneer removal; however, these surveys may assist in determining the locations where larger-scale removal would be most informative. Additionally, by performing a non-destructive survey prior to the veneer removal, the accuracy of the non-destructive method can be assessed, which may be beneficial to other aspects of a given project.

WALL TIE CORROSION AND ANCHOR DEFICIENCIES

The corrosion deterioration of veneer anchors, or of the framing supporting the veneer (such as steel stud framing), is a topic worthy of extensive and detailed discussion beyond the scope of this document. However, a brief discussion is warranted herein due to the severity of the problems that can result from veneer anchor corrosion. The corrosion deterioration of veneer anchors within a cavity wall is typically not visible and often goes unrecognized until a failure occurs. Figures 13 and 14 depict conditions observed after a portion of a veneer wall collapsed at a school campus building. Veneer anchors had corroded through their cross section within the wall cavity. However, the deteriorated condition of the anchors was not known prior to the collapse, which occurred suddenly. It should be noted that this structure was not located in a coastal area.

Figure 13. Corroded and failed veneer anchors at a collapsed veneer wall.

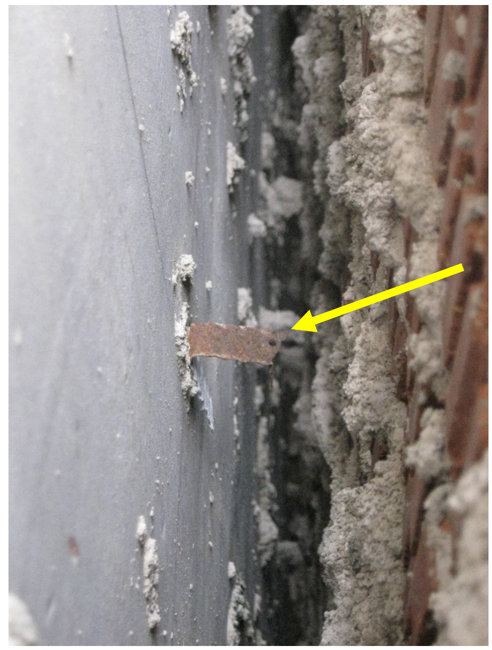


Figure 14. Corroded and failed veneer anchor at a portion of the wall that had not yet collapsed.

Awareness of the potential for veneer anchor corrosion has increased over time and with changing construction methods related to veneer walls (BIA 2003). The authors have observed veneer anchor corrosion to varying degrees and have observed the beginning stages of base steel corrosion in veneer anchors very early in their service lives, even in non-coastal locations. The authors have also observed base steel corrosion at galvanized veneer anchors in buildings one-year of age and less (Figure 15).

Prolonged or severe exposure to moisture or other deleterious elements (such as chlorides or acids) may compromise the veneer attachment over time due to deterioration of the veneer anchors or structural system to which the anchors are attached. The potential for corrosion of veneer anchorage is a function of exposure conditions for a given building (dependent on geographic location); construction material selection and compatibility; and detailing, workmanship, and maintenance.

Figure 15. Veneer anchor corrosion at a structure less than one-year of age.

Deficiencies in the veneer anchors themselves can also affect the integrity of an anchored veneer. Some common deficiencies include the use of the wrong anchor type or material (such as galvanized instead of stainless steel), improper installation of the anchor, and improper anchor placement.

Deficient or deteriorated masonry veneer attachments have the potential to result in sudden or premature veneer failures, and associated safety hazards and damage to property. Due to the concealed nature of the veneer anchorage, non-destructive and destructive methodologies may be required to evaluate a masonry veneer system. Over the course of multiple evaluations of masonry veneer systems, the authors have determined that a combination of the evaluation methodologies described above can be reliably used to determine the characteristics, distribution, and condition of masonry veneer anchors.

CONCLUSIONS AND FURTHER READING

While masonry veneer anchors are hidden, non-destructive testing can be used to accurately determine the anchor locations. Data from non-destructive surveys of masonry veneers can be used to evaluate the distribution of the veneer anchors and to identify locations for further testing and detailed observation.

Non-destructive surveys to determine veneer anchor locations, followed by minimally-invasive destructive evaluation of the cavity or localized veneer removal, is an effective method to evaluate the condition of veneer anchors within cavity wall systems, including the identification of veneer anchor deficiencies or deterioration.

While this paper is presented to a primarily American audience, the authors would like to highlight some resources from outside the United States that may be useful to the reader. The Building Research Establishment (BRE) in the United Kingdom has published multiple documents related to the assessment of masonry veneer anchors, the corrosion of anchors (wall ties), and the repair of anchored veneer. These documents include BRE Digest 329 (*Installing wall ties in existing construction*), BRE Digest 401 (*Replacing wall ties*), and BRE Information Paper 13/90 (*Corrosion of steel wall ties: recognition and inspection*).

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