Introduction
This ARRISCRAFT•NOTE discusses the basic principles of symptom identification and fault diagnosis of masonry-related building envelope problems.

Distinctions between building maintenance and building envelope repair are examined. By developing an understanding of the relationships between symptoms and faults, the reader should gain a clear understanding of how the long-term performance of the building envelope is affected.

Further, a variety of common symptoms and their underlying causes are discussed relative to possible repair activities.

Is it Maintenance or Repair?
Just as in the world of medicine symptoms are not necessarily the cause for the "illness" – or in the case of building forensics, a building envelope problem. Rather, they are the clues that help the investigator determine what "treatment" may need to be undertaken,

Distinguishing whether a symptom is indicative of a building envelope problem or simply the need for normal building maintenance will not necessarily be clear cut. Typically, symptoms necessitating only routine maintenance are static; whereas, dynamic symptoms are more commonly a sign that repair of a building fault is first required. A sound understanding of building forensics will be required in order to distinguish whether the symptom is either static or dynamic in nature.

Maintenance of Masonry Veneer
Just as with all other types of building cladding systems, masonry veneer will experience predictable levels of deterioration over time due to its continuous exposure to its local environment (*ref. Drysdale, R.G. and Sutter, G.T., Exterior Wall Construction in High-Rise Buildings, Canada Mortgage and Housing Corporation, pg. 17-1*). Such deterioration is considered acceptable and unavoidable; thereby necessitating that building owners undertake scheduled maintenance of their building's cladding system. This maintenance may be either proactive, reactive or some combination of both.

Symptoms indicative of deterioration that necessitate maintenance should not be attributed to a fault or defect in the veneer wall system. Rather, they are symptoms that may be expected to occur during the service life of the building (*ref. Cody, Gina P., Deterioration of Masonry, Causes and Prevention, Seventh Canadian Masonry Symposium, June 4-7; pg. 833*).

Symptoms requiring maintenance of the masonry veneer may include mortar crack repair, general removal of pollutant build up and initial efflorescence, joint sealant repair, and the removal of graffiti.

Mortar joint cracks that require re-pointing as a part of a maintenance program typically could result from:
- singular occurrences of deflection and/or settlement;
- curling of a structural concrete slab; or
- hairline shrinkage cracks.

Cracks resulting from singular occurrences of settlement or deflection tend to appear within the first annual cycle and do not increase in size or thickness thereafter, provided they are not left exposed to the effects of mortar erosion and freeze-thaw cycling indefinitely. They will typically have a tapered profile with the joint appearing widest at its lowest point.

As a concrete slab cures, it may curl upwards at its ends. When masonry is attached to or supported by such a slab, a horizontal crack may occur.

These types of cracks rarely re-occur once repaired.

Hairline shrinkage cracks are generally only surface cracks that do not penetrate the entire bed of the joint. They result from the shrinkage of the mortar as it dries and are more likely to occur when mortars of high cement content are used, when the mortar joints are installed too wide, when large masonry units with clean cut arris are used, or when tooling of the joints is inconsistent or improperly preformed.

Hairline shrinkage cracks are generally considered to be an aesthetic issue rather than a wall performance issue. Progressive deterioration of these cracks is not expected. Their repair is usually undertaken at the discretion of the building owner for aesthetic purposes.

Discolouration of the masonry may result gradually from the building's exposure to pollutants within the surrounding environment or from initial efflorescence forming on the wall's surface. Over time the deposit of pollutants on the building's façade may be deemed unsightly and should be removed from the masonry surface using recommended cleaning methods. Initial efflorescence, sometimes referred to as building bloom, is expected to occur during a building's first annual

cycle. Typically, such deposits will disappear after one or two rainfalls and should not reoccur.

Joint sealants used in conjunction with masonry veneer have a service life and will most likely need to be replaced a number of times during a building's life cycle. The frequency of this replacement is largely dependant on the quality and composition of the sealant. If not maintained on a regular basis, deteriorated sealant may result in water penetration and joint failure, leading to larger building envelope problems.

Graffiti and other such instances of vandalism may also need to be addressed. Reputable masonry manufacturers, in consultation with cleaning product manufacturers, can assist building owners on a case-by-case basis to solve aesthetic maintenance issues.

Symptoms Necessitating Fault Repair

Too commonly our building industry perceives wall cracks, water leaks, efflorescence, unit spalling, and unit displacement as building or product faults rather than what they really are - symptoms of a fault (*ref. Genge, Gerald R., Repair of Faults in Masonry Building Envelopes, Seventh Canadian Masonry Symposium, June 4-7, 1995; pg 840*). Considerable effort is sometimes spent examining, categorizing and documenting symptoms rather than the actual root causes of the noted distress or deterioration. Basing repair decisions solely on these symptoms without determining their underlying causes, however, will not result in acceptable results.

Symptoms that can be indicative of a building envelope problem include:

- cracked mortar joints and masonry units;
- displaced masonry units;
- unit spalling and scaling;
- unit staining; and
- recurring instances of efflorescence.

Prior to any restoration work being undertaken, the nature of the problem should first be accurately identified.

Fault Diagnosis and Determining Treatment

Cracked mortar joints and masonry units can be a symptom of uncontrolled differential movement. The cracks may take a variety of different shapes and patterns, and these differences will help with diagnosing the nature of the underlying cause of the cracking.

Vertical Step Cracks indicate inadequate accommodation for movement from volumetric change. These types of cracks are most prevalent at building corners and along parapet walls where the sum of the forces acting on the walls is typically the greatest. Without adequate accommodation for movement a masonry wall will create its own movement joint by cracking along the weakest plane, generally in a stepped fashion along the mortar-unit interface. Repairing such a crack without providing additional movement capability within the wall assembly will only result in further cracking.

Diagonal Step Tapered Cracks are indicative of differential settlement or deflection, where one portion of a structure has settled more than its adjacent parts. Prior to repairing such cracks as a maintenance item, it should first be determined if the crack is static or dynamic. If static, then re-pointing the cracked joint will resolve this condition. If the crack is determined to be dynamic, however, the solution may not be quite so simple. An investigation of concealed conditions might be necessary to determine the scope and nature of the settlement or deflection with remedial action first being undertaken to resolve the source of movement before the crack repair can commence.

Inadequate diagonal wind bracing of the structural back-up walls, particularly relevant when more flexible steel stud is used, has also been known to result in cracking of masonry veneer. Such conditions must be rectified prior to repairing the cracked masonry wall. This is generally not a simple or cheap exercise as it requires the dismantling of either the veneer wall or the finished interior to gain access to the structural wall components. Alternatively, breaking the wall surface into smaller panels by incorporating additional movement joints might better accommodate the movement of the veneer materials without resulting in uncontrolled cracking.

Horizontal Cracks may result along masonry bed joints from shortening of the structural frame or deflection of shelf angle supports if adequate accommodation for this vertical movement is not incorporated in the veneer by means of horizontal movement joints. Such cracking is usually accompanied by unit displacement.

Refer to ARRISCRAFT•NOTE Vol. I, No. 1, titled Building Movement Joints for further information pertaining to the control of differential movement.

Equally, inadequate lateral restraint of the veneer due to an insufficient quantity or quality wall ties could result in applied loads that will crack the mortar. Such cracks are generally accompanied by portions of the masonry "bowing" out from the plane of the wall. Prior to crack repairs being undertaken, the masonry veneer would need to be laterally secured to the structural back-up using purpose-made repair connectors.

Unit Displacement is normally a symptom of uncontrolled differential movement. Units become displaced when sufficient stress has been allowed to act upon the unit such that the combination of the gravity load, shear resistance and lateral restraint normally holding the unit in place have all been exceeded. Such stresses could result from inadequate lateral load transfer or uncontrolled cyclic volumetric change resulting from inadequate accommodation for movement or moisture infiltration.

As noted above inadequate accommodation for movement resulting from volumetric change will crack the veneer, and masonry units in this vicinity will be most susceptible to displacement. Typically, the larger the unit is, the more likely it will become displaced after cracking has occurred. By their very nature larger masonry units will have a lower ratio of mortar-to-unit area compared with smaller units. As such, the mortar holding these units in place is more susceptible to further deterioration after initial cracking has occurred, and this will eventually lead units that are free to be moved by the stresses being imposed on them. Units that have a means of providing a mortar key may exhibit less significant displacement deepening on the applied stresses.

As with vertical step cracks, this displacement is most prevalent at building corners and along parapet walls where the sum of the forces acting on the wall is greatest. Prior to resetting displaced units within the wall, it is essential that additional accommodation be made for differential movement, normally accomplished by incorporating additional movement joints within the general location of the displacement.

Uncontrolled moisture penetration could result in the progressive erosion of the mortar joints until there is no longer a sufficient quantity of mortar to secure the wall tie system to the veneer. Under this condition wind or seismic loads could result in unit displacement. In colder climates water resting within the wall will also be subjected to freezing, causing its volume to expand and potentially imparting a force large enough on the masonry to also cause it to move.

Displacement may also occur due to shortening of the structural frame or deflection of shelf angle supports if there is inadequate accommodation for vertical movement.

Equally, inadequate lateral restraint of the veneer due to an insufficient quantity or quality of wall ties could result in applied loads gradually displacing the masonry. Refer to ARRISCRAFT•NOTE Vol. I, No. 3, titled Connectors Part I – Masonry Ties for further information regarding wall ties and lateral restraint requirements for masonry veneer walls.

Spalled and Scaled Units can be indicative of poor moisture management or uncontrolled differential movement. Masonry units will spall or scale once they become saturated by a continuous source of moisture and are then subjected to freeze-thaw cycling. The application of water repellent sealers to some masonry units may also contribute to spalling or scaling as they tend to inhibit the masonry's ability to breathe and trap moisture just behind the unit's surface. Sealed units will remain wetter longer and could be damaged by moisture freezing within the unit's pore structure and subsequently damaging the unit's face.

Some typical sources of moisture leading to unit saturation include roof leaks, improperly constructed flashing membranes, non-functioning air/vapour barrier membranes that allow condensation to occur, poorly detailed sills, caps and copings, and clogged or non-existent weep hole vents. Wind-driven rain is unlikely to cause a continuous state of masonry saturation unless drainage detailing is deficient.

Spalling may also occur when shortening of the structural frame or deflection of shelf angle supports impart stress into the masonry units below. This could occur if inadequate accommodation for vertical movement is included in the form of horizontal movement joints below shelf angles.

In colder climates extended exposure to de-icing compounds has also been known to contribute to spalling and scaling.

Prior to replacing or repairing spalled and scaled units, the source of moisture must be identified and repaired; otherwise, the problems will persist.

Stained Units may be a symptom of poor moisture management or continuous exposure to sources of moisture. Saturated masonry units, particularly lighter coloured units, will appear darker wherever the moisture has been wicked into the material. The moisture may include particles of dirt and pollution that will be deposited within the pore structure of the masonry. For example, masonry units that are installed in direct contact with topsoil will draw a quantity of dirt-laden moisture from the topsoil into its pore structure. Similar conditions will occur from water run-off, where the moisture contains pollutants, such as from the tops of wall caps, sills, copings, etc. After lengthy exposure to these conditions, the resulting stain may prove difficult to remove.

The continual presence of moisture could also lead to the formation of biological stains such as mould and

mildew within the pore structure of the masonry units. Such stains may prove difficult to remove due to their organic nature. The growth must be stopped and then the stain removed. There are propriety agents that can be used, but their effect on the masonry's appearance must be tested.

Cleaning stained masonry without first determining the cause of the staining will most likely not result in a satisfactory solution. The source of the moisture must first be identified and rectified if subsequent staining is to be avoided.

Recurring Efflorescence is normally indicative of poor moisture management. Efflorescence is a crystalline deposit of water-soluble compounds on the surface of unit masonry. In order for efflorescence to occur soluble salts must be present within the wall construction; a source of water must be present and in contact with the soluble salts for a sufficient period of time to permit then to dissolve; and the migration of these salts in solution to the masonry surface where the moisture is allowed to evaporate.

The most realistic means for preventing recurring efflorescence is to limit the extended presence of moisture within the wall assembly. Two considerations which must be addressed to successfully reduce efflorescence–causing moisture within the wall are to:

- prevent sufficiently large quantities of water from penetrating the wall; and
- ensure that any water penetrating the wall is allowed to quickly leave the wall assembly, thus minimizing absorption by the masonry units and the mortar.

Refer to ARRISCRAFT•NOTE Vol. II, No. 1, titled Efflorescence for further information pertaining to the prevention of efflorescence in masonry walls.

When recurring efflorescence is noted as a symptom of a building fault, the source of the moisture penetration and the cause of its retention should both be identified and rectified prior to removing the efflorescence.

Summary

This ARRISCRAFT•NOTE discusses the basic principles of symptom identification and fault-diagnosis of masonry-related building envelope failures. Distinctions between maintenance and repair, and symptoms and faults are described, while a variety of common symptoms and building faults are discussed relative to their repair.

The information and suggestions contained herein are based upon the available data and information published by the listed references and the experience of Arriscraft International architectural and engineering staff. More detailed information may be found by referring to any of the related references listed below.

The information contained herein must be used in conjunction with good technical judgment and a competent understanding of masonry construction. Final decisions on the use of the information contained in this ARRISCRAFT•NOTE are not within the purview of Arriscraft International and must rest with the project designer or owner, or both. It remains the sole responsibility of the designer to properly design the project, ensure all architectural and engineering principles are properly applied throughout, and ensure that any suggestions made by Arriscraft International are appropriate in the instance and are properly incorporated through the project.

Related References

1. Aberdeen Group, Masonry Inspection and Maintenance, Aberdeen's Magazine of Masonry Construction, 1994.
2. Brick Industry Association, Technical Notes on Brick Construction.
3. Canada Mortgage and Housing Corporation, Best Practice Guides – Building Technology.
4. Drysdale, R.G. and Sutter, G.T., Exterior Wall Construction in High Rise Buildings, Canada Mortgage and Housing Corporation.
5. Cody, Gina P., Deterioration of Masonry, Causes and Prevention, Seventh Canadian Masonry Symposium, June 4-7, 1995; pp. 833-839
6. Genge, Gerald R., Repair of Faults in Masonry Building Envelopes, Seventh Canadian Masonry Symposium, June 4-7, 1995; pp. 840-849

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