Arriscraft.NOTE Series

Volume 1

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Introduction

This ARRISCRAFT•NOTE discusses the proper placement and construction of movement joints in unit masonry veneer walls.

There are basically two distinct types of movement joints used in construction: *elastic* and *inelastic*. Both of these joint types are designed to perform a specific function, and they should not be used interchangeably.

Inelastic movement joints include *construction joints* and *control joints*.

- *Construction joints* are used wherever the construction work is to be interrupted. They are usually located where they will least impair the strength of the structure.
- *Control joints* are largely used in concrete unit masonry construction to create a plane of weakness. When used in conjunction with joint reinforcement, they control the location of cracks due to volume changes resulting from shrinkage and creep. They are not generally sufficient to accommodate net material expansion.

Elastic movement joints include *building expansion joints* and *expansion joints*.

- *Building expansion joints* are used to separate a building into discrete sections so that stresses developed in one section will not affect the integrity of the entire structure.
- *Expansion joints* are used mainly in clay brick, calcium silicate, or stone masonry construction. They are used to segment the veneer to prevent cracking due to changes in temperature, moisture expansion, elastic deformation due to loads, and creep. They may be horizontal or vertical.

It is the elastic-type movement joint that is most appropriate for use in a masonry veneer application, and requirements for this type of joint will form the basis of the following discussion.

Movement Joints in Masonry Veneer

Movement joints can be constructed in a variety of different ways. They may include waterstops and pre-moulded foam or neoprene pads as barriers to keep mortar or other debris from clogging the joint. These materials must be highly compressible and elastic in nature in order to accommodate the expansion and contraction of the veneer materials. As such, the use of fiberboard or other similar materials are not recommended for use in movement joints.

No solid materials should bridge the movement joint as they would restrict movement and not allow the movement joint to perform its intended function.

Materials for Movement Joints

A good quality backer rod and joint sealant should be used to seal the exterior of the movement joint against moisture and air penetration. The sealant material should be selected by the designer to be highly elastic, resistant to weathering and ultraviolet radiation, and compatible with the unit masonry materials, including any adjacent materials such as flashing membranes or metal elements.

The size of the movement joint should be considered when selecting the type of joint sealant. The sealant must be able to span the joint and accommodate the anticipated movements of all materials. As a rule of thumb, joint sealants used in movement joints should typically have a width-to-depth ratio of 2:1 in order to ensure adequate protection against moisture and air penetration (Figure 1).

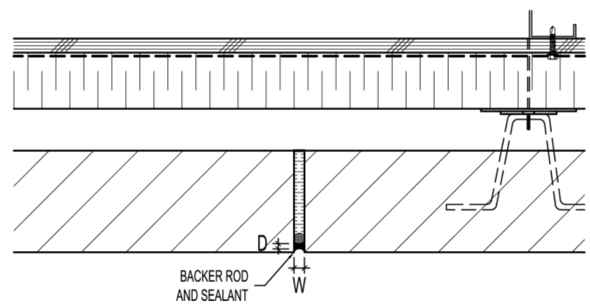

Figure 1

The inclusion of a good quality backer rod is important to proper joint design. The backer rod is used to:

- act as a bond breaker, forcing the sealant into two-point adhesion. It should be noted that sealant may fail prematurely when put into three-point adhesion as this subjects the sealant to shear stress in addition to tension/compression;
- achieve the required 2:1 width-to-depth ratio of the sealant; and
- provide a firm surface against which tooling can be done. Proper tooling optimizes the joint's weather resistance and ensures better adhesion of the sealant. The backer rod allows the sealant to be tooled into an hourglass shape, providing maximum flexibility.

For further information refer to ARRISCRAFT•NOTE (Vol. IV, No. 4) Important Criteria for Sealant and Backer Rod Selection.

Sizing of Movement Joints

Vertical movement joint frequency and size should be designed to accommodate the anticipated movement of the veneer materials. The joints must be of sufficient size to contend with the anticipated movements, without being so large as to be difficult to weather-proof. Typically, joints sized to resemble a mortar joint will be adequate to accommodate the anticipated movements and still be easily sealed against the elements.

The design of horizontal movement joints depends largely upon the anticipated loads and resulting deflections which are expected to occur at their particular locations.

Placement of Movement Joints

The actual location and frequency of movement joints is dependent upon the configuration of the structure as well as the expected amount of movement dictated by micro-environmental factors. They need to be designed as part of the building envelope by the designer and their location and extent must be clearly indicated on the building elevations. As a general rule of thumb, movement joints should be located at the following locations:

- at changes in wall direction, such as building corners;
- at wall openings, such as windows and doors;
- at changes in building height, such as building junctions;
- at major changes in thickness of wall, such as pilasters;
- at periodic lengths of continuous wall;
- at changes of building materials; and
- below shelf angles.

Corners: Walls perpendicular to one another will expand towards their juncture, typically causing distress at the first head joint on either side of the corner. Movement joints should be placed near corners to alleviate this stress (Figure 2).

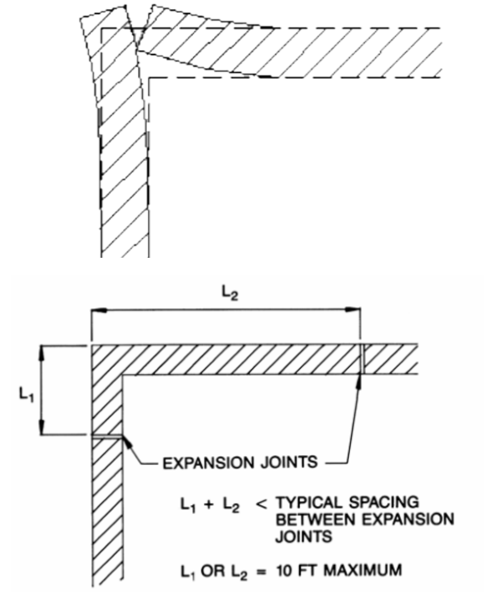

Figure 2

Intersections, Offsets and Setbacks: Parallel walls expand towards the offset, rotating the short masonry leg or causing cracks within the offset. Movement joints should be placed at the offset to allow the parallel walls to expand (Figure 3). Intersecting walls not required to be bonded should also include a movement joint at the intersection.

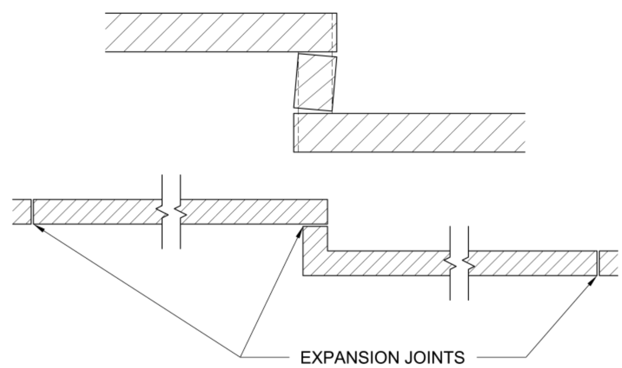

Figure 3

Wall Openings: More movement will tend to occur above and below openings due to the change in the wall's mass. The differential movement between areas of different wall mass may cause cracks to emanate from the corners of the openings. As these openings also tend to "weaken" the wall, they act as naturally occurring movement joints.

It is often desirable to locate the veneer movement joint along the edge or jamb of the opening. In cases where the masonry above the opening is supported by steel shelf angles connected directly to the building structure, a vertical movement joint can be placed alongside the opening, continuing through the horizontal support.

More commonly, however, masonry above the opening is supported by a loose steel lintel, thereby necessitating special detailing and construction of the movement joint at these locations. Consideration of the steel angle's need to expand and contract independent of the masonry necessitates incorporating a slip plane along the bed of the lintel (Figure 4). If this cannot be done, it may be better to locate the movement joint elsewhere, perhaps midway between openings.

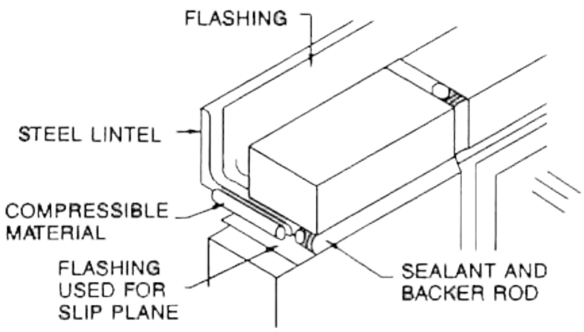

Figure 4

Junctions/Changes in Wall Height: Just as with wall openings, large variations in wall height should include a movement joint at the juncture to accommodate the differential movement tendencies of the two different wall masses.

Periodic Lengths of Continuous Wall: Large expanses of masonry veneer will, by virtue of the aggregate sum of their individual dimensional changes, experience significant strain over the length of the wall. To alleviate this effect, continuous vertical movement joints should be incorporated along the length of the wall, generally at a spacing of between 20-25 feet (6-7.6 metres).

Changes in Building Materials: Different materials will react differently to the effects of thermal and moisture change. For example, aluminum frames and masonry products will expand and contract at widely differing rates. The effects of such differential movement need to be accounted for and accommodated by the inclusion of a properly sized movement joint.

Below Shelf Angles: Horizontal movement joints are required wherever the masonry veneer has been supported on a shelf angle outside the frame. They are typically created by providing a space beneath the angle for differential movement to occur (Figure 5). Differential movements of the veneer materials and the structural frame should both be considered.

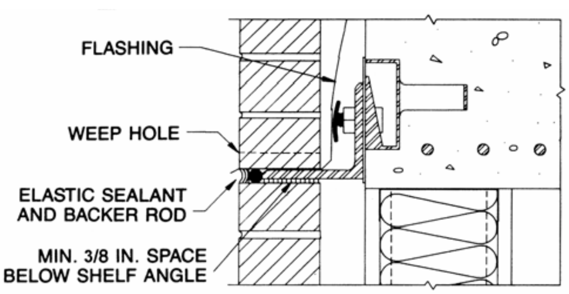

Figure 5

Other Considerations Affecting Placement

Placement of movement joints may also be influenced by additional factors.

Parapets are exposed on three sides to extremes of moisture and temperature. This may cause substantially different movement from that of the wall below. Placing additional movement joints at these locations may be good practice.

Wherever spandrel wall sections are supported by a beam or floor slab, additional vertical movement joints may be required.

Allowance for differential movement between the building veneer and structural elements (such as steel beams, anchor points for signage, or utilities) should always be provided.

In certain circumstances, substrate choice may dictate the location of movement joints. Poured concrete or concrete masonry unit (CMU) substrates require control joint placement within the structural back-up. In such cases, movement joints within the masonry veneer must align with the substrate control joints (Figure 6).

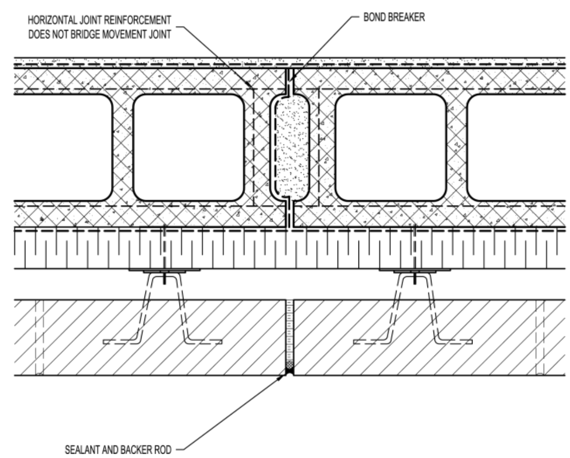

Figure 6

Aesthetic Considerations

Movement joint design and placement can impact the overall aesthetics of the building façade.

Following are considerations that can minimize their visual impact:

- Pigment vertical movement joints to match the color of the adjacent veneer units (Figure 7). When adjacent unit color changes up the height of the joint, change the sealant color to match (Figure 8).
- Pigment horizontal movement joints to match the color of the mortar joints.
- Silt the movement joint to create a mortar-like appearance (Figure 9).

Alternatively, movement joints may also be accentuated as part of the architectural design of the building face

(Figures 10 and 11). Their placement in the wall can create symmetry (Figure 12) and create aesthetically pleasing façades.

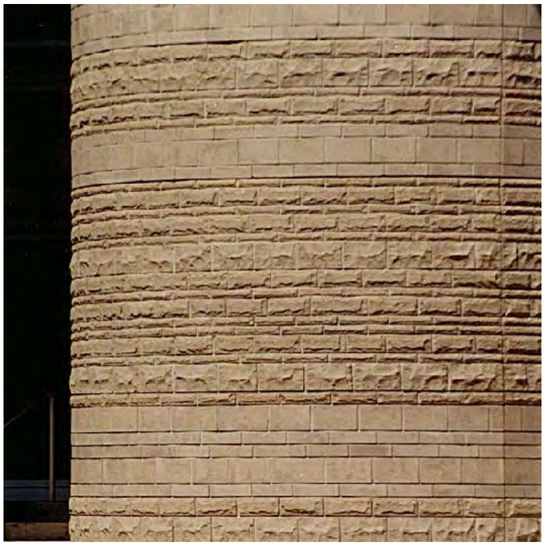

Figure 7: Sealant colored to match color of adjacent veneer units.

Figure 8: Change sealant color within the vertical joint to match changing unit colors up the height of the wall.

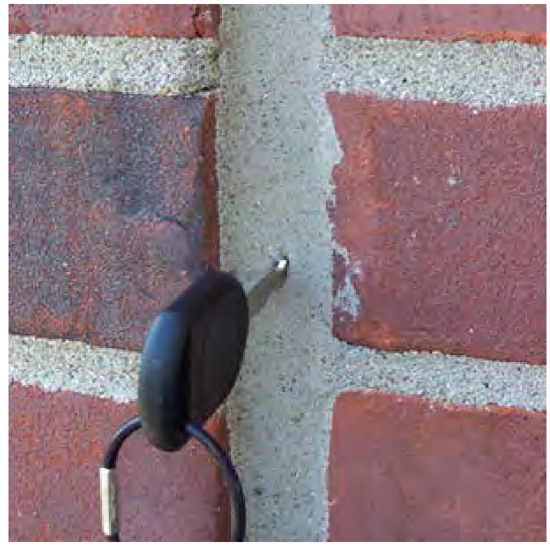

Figure 9: Silt the sealant surface to emulate mortar.

Figure 10: Movement joint placed at continuous notch in veneer.

Figure 11: Movement joint integrated into design.

Figure 12: Placement of movement joints creates wall symmetry.

Summary

This ARRISCRAFT•NOTE describes the different kinds of joints found in building construction and discusses the appropriate design and use of movement joints in masonry veneer construction.

Movement joints are used in masonry construction to allow for the differential movement generated by materials as they react to their own properties, environmental conditions and loads. In general, vertical movement joints should be used to break the masonry into rectangular elements that have the same support conditions, the same climatic exposure and the same through-wall construction. Horizontal movement joints should be placed below shelf angles supporting masonry.

The information and suggestions contained herein are based upon the available data and information published by the listed references and the experience of Arriscraft 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 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 are appropriate in the instance and are properly incorporated through the project.

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Introduction

This ARRISCRAFT•NOTE discusses the rain screen principle and compares cavity walls with rain screen walls.

Walls built as solid multi-wythe structures rely heavily upon the mass of the wall materials to resist moisture penetration. Researchers eventually realized that the exterior wythe of a masonry wall could not be made totally watertight. Exterior wall surfaces become wet, and openings eventually develop within the wall, thus permitting moisture infiltration.

In 1962 a Norwegian researcher, Birkeland, identified six major sources of moisture leakage:

- wind-induced air pressure differences,
- pressure-assisted capillary,
- gravity,
- kinetic Energy,
- air currents, and
- updrafts.

Conventional means of managing moisture resist most of the major causes of moisture leakage, but wind-induced air pressure is not quite so easily counteracted. Birkeland concluded that there was no practical method for obtaining total water tightness in wall systems composed of joints when a pressure gradient exists across the exterior rain barrier.

This research was further developed by the Canadian National Research Council, which published Canadian Building Digest 40, Rain Penetration and Its Control. This publication remains one of the primary reference sources on the topic. It states that, "*...through wall penetration of rain can be prevented by incorporating an air chamber into the joint or wall where the air pressure is always equal to that on the outside.*" This remains the basic principle of a rain screen wall.

Rain Screen Versus Cavity Wall

Rain screen wall systems and cavity walls are not one and the same. Admittedly, both incorporate a cavity to drain any moisture which may have entered the wall, but the cavity wall stops there. It does not allow air pressure in the cavity to be equalized with external pressures, and the interior wall assembly may or may not include air/vapour barrier membranes designed to restrict the movement of water vapour and air through the wall.

The basic premise of the rain screen principle is to control all forces that can drive moisture through the wall system. Its primary function is to restrict the passage of moisture through the wall caused by wind-induced pressures.

The critical components of a rain screen wall are:

- an exterior barrier containing protected openings that permit the passage of air but not water,
- a confined cavity behind the rain screen in which air pressure is essentially equalized with the exterior,
- insulation securely fastened to the outer face of the interior wall system, and
- an interior wall system, incorporating an air and vapour barrier capable of resisting the passage of air and water vapour, and capable of withstanding all required design loads.

In cavity wall systems the difference in air pressures across the exterior cladding is a significant force, causing infiltration of air and water on windward faces. The air pressure in the cavity becomes relatively less than the external air pressure along these building faces, and any moisture hitting the masonry veneer will be driven through any openings in the veneer and come in contact with the interior wall.

In a rain screen wall the cavity has had its air pressure equalized with that of the air outside by the presence of sufficiently designed openings. These openings allow air to flow freely within the cavity. Rain penetration into the cavity should be reduced because the effects of differential pressure have been essentially eliminated. The resultant wind load will be imposed on the inner layer of the wall assembly. For that reason it is important to install flashing membranes and air/vapour barrier membranes to produce an air-tight, weather-resistant assembly at the inner layer, thereby reducing the potential for moisture infiltration.

Equalizing the Pressure

In order to ensure the equalization of cavity pressure to external air pressure a number of requirements need to be satisfied, including:

- Compartmentalization of the air space;
- Adequate venting of the compartments; and
- Clear compartments free of mortar blockages.

Compartmentalization: Wind pressure flowing around a building creates a distribution of positive and negative pressures over the face of the exterior cladding. If the cavity of the rain screen wall is continuous, pressure equalization will not occur due to lateral airflow. To prevent lateral airflow within the cavity it should be divided into separate air chambers or compartments. The size of the compartments depends upon the degree of differential pressure anticipated at specific points around the building. Areas of the wall where higher differential pressures are anticipated should be designed with smaller compartments; whereas, areas having smaller differences in pressure may be larger.

A typical example where compartmentalization should be incorporated would be at external corners where high differences in air pressure could result in lateral airflow across the cavity and thus a loss of pressure equalization.

Ventilation: To provide pressure equalization it is also necessary to design a series of openings within the rain screen veneer. These openings connect the cavity with the exterior and should be positioned at the top and bottom of each compartment. A typical method for incorporating these openings in sufficient quantity to ensure pressure equalization of the cavity is by placing cell vents and weepholes respectively at the top and bottom of all cavities. When the vent is in the form of an open head joint, a suitable spacing of 600 mm (24") on centre should prove adequate in most instances.

Mortar Blockage: When constructing a rain screen wall, it is equally important to ensure that the cavity remains free of mortar droppings and protrusions. Mortar droppings, which collect at the base of a cavity, block the free drainage of moisture as well as restrict the free flow of air between the cavity and the exterior. Restricted airflow inhibits pressure equalization.

Summary

This ARRISCRAFT•NOTE describes the pressure equalized rain screen principle as it applies to masonry veneer and cavity wall systems and discusses recommended design guidelines to reduce rain penetration through exterior wall assemblies.

The rain screen principle is a superior method of designing and constructing a building envelope, controlling the many factors that contribute to moisture penetration. It is based on the principle of equalizing air pressures within the drainage cavity with those on the exterior face of the building, thereby reducing the possibility of moisture penetration resulting from difference in the wind-induced air pressure. When designed and constructed properly, this wall system provides the best possible protection against moisture infiltration and subsequent building damage.

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 judgement 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.

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Introduction
This ARRISCRAFT•NOTE is the first in a series of two technical papers dealing with the issues relating to connectors used in wall construction. Criteria relative to the selection of wall tie systems will form the basis of discussion for this paper. Part II will discuss criteria relative to selecting an appropriate anchor system for dimensional stone cladding.

Selecting the proper masonry wall tie system for a specific application can be both confusing and frustrating. Designers can be overwhelmed by the variety and specialized nature of the many different types of tie systems available. Often times they turn to the masonry unit manufacturer for their recommendation; but without a detailed understanding of the building's structural design, the applicable loadings, and other such criteria, no unit masonry manufacturer can reliably offer such advice. A building's tie system must be designed by a professional based upon the specific criteria relevant to the building's life expectancy, type and relative stiffness of structural back-up, wind and seismic design loads, exposure to moisture, cavity width, ease of installation, and the nature of surrounding or adjacent wall materials.

These considerations, combined with issues of availability and cost, will determine the exact type, size and finish of tie required.

Function of Wall Ties
Typically, wall ties connect two or more wythes of masonry together or connect a unit masonry veneer to a structural back-up. They generally transfer lateral loads while permitting in-plane movement to accommodate differential movement.

To fulfill these functions adequately a wall tie must be easily installed, be securely attached or embedded, have sufficient strength and stiffness to transfer lateral loads with as little deformation as possible, have a minimum amount of mechanical play, provide adequate resistance to the transfer of moisture across a cavity, and be corrosion resistant.

Masonry Veneer and Cavity Walls: When a cavity or air space exists between two or more wythes of masonry, wall ties are usually required in order to transfer lateral loads by both axial compression and tension. In the case of a masonry veneer wall where the back-up wall is designed to resist the entire lateral load, these wall ties must support the masonry veneer and transfer the loads from the veneer to the structural back-up. By tying the masonry veneer to a sufficiently stiff back-up with stiff wall ties installed at the correct spacing, the potential for bending in the veneer will effectively be reduced, thus minimizing flexural cracking.

Outer wythes of cavity or masonry veneer walls typically experience greater movement resulting from thermal and moisture gradients and less movement as a result of elastic or inelastic deformations compared to the interior wythe. This can result in substantial differential movement between the two wythes. As such, many wall tie systems incorporate a means to allow unrestrained, relative movements to occur in directions parallel to the plane of the wall.

Coupled cavity walls are multi-wythe walls which have had their wythes tied together with flexurally stiff connectors in order to increase bending strength and stiffness. When considering the design of coupled cavity walls, it is critical to also consider the effects of differential movement.

Composite Walls: In a composite masonry wall the grout-filled collar joint acts as a shear transfer mechanism between wythes. Whenever shear strengths along the interface are exceeded, the wall ties will act to resist relative movement. They must also be designed to be strong enough during construction to withstand the large tensile forces being imposed on them during grouting operations.

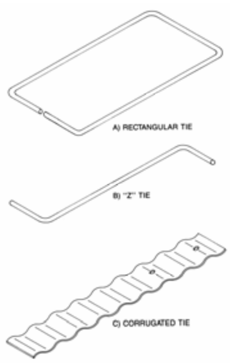
Wall Tie Types
There are a wide variety of tie systems and types available. No single type of wall tie is "*better*" than another. Rather, each type of wall tie has been designed to perform a specific task. It is critical for designers to understand what types of tie systems are available and what they are each designed to do.

Wall ties are generally classified by their:

- type of material;
- geometry;
- shape of material used;
- stiffness;
- adjustability;
- continuity; and
- corrosion resistance.

Wall tie systems have been designed for cavity, multi-wythe, grouted and veneer wall systems. These include unit ties, continuous horizontal joint reinforcement, adjustable ties and repair connectors. The first three types are used primarily in new construction; whereas, repair connectors are usually used in retrofit applications.

Unit Ties: Unit ties are comprised from a single component, either sheet metal or wire. These are available in various configurations, including rectangular wire ties, Z-wire ties, and corrugated strap ties.



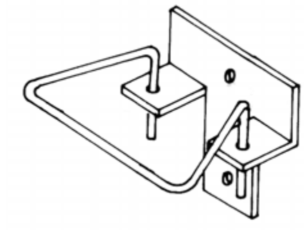
Rectangular ties and Z-wire ties are used to bond walls constructed of two or more masonry wythes. Whereas, rectangular ties can be used to bond both hollow or solid units, Z-wire ties should only be used to bond solid units.

Corrugated strap ties are typically used in low-rise applications where a masonry veneer is connected to wood frame construction. Building codes or construction standards may limit their use based upon the width of the cavity. They are not recommended for use when incorporating masonry veneer over steel studs, masonry-backed cavity walls, multi-wythe walls or grouted masonry walls.

Joint Reinforcement: Continuous horizontal joint reinforcement is prefabricated from similar components combined in a variety of configurations. They are designed to produce a lightweight yet strong method of bonding two or more wythes of coursed masonry together and provide the dual function of wall tie and horizontal joint reinforcement to control flexural cracking. The most common types are the ladder, truss and tab types.

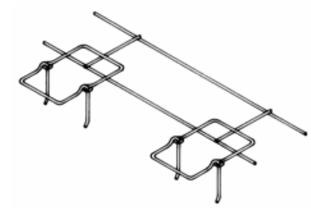
These are recommended for use in multi-wythe solid walls, masonry cavity wall, and grouted masonry walls. Truss-type joint reinforcement may restrict horizontal differential movement resulting from temperature or shrinkage differentials between wythes unless vertical expansion joints are provided at regular intervals.

Adjustable Ties: Adjustable ties are commonly two-piece systems. They are primarily intended to accommodate construction tolerances common in multi-material wall construction where non-coursing wythes of masonry are bonded together. One piece is generally installed as the back-up is constructed and the other piece as the veneer wythe is constructed. Typically they can accommodate larger differential movements than standard unit ties or joint reinforcement. Such flexibility, however, also comes with is own share of potential problems. Improperly positioned ties could result in large vertical tie eccentricities. At the very worst, if installed in a location beyond the scope of its adjustability, the tie could be rendered useless. Adjustability should never replace proper design and construction practices.



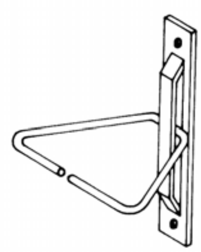
Some examples of adjustable tie types include pintles, slotted, and fastener adjusted.

- Pintle ties are typically made with bent wire and provide vertical adjustability by the pintle passing through a restraining eye or other opening in the receiving unit.



Pintle Tie

- Slotted ties employ a triangular wire tie in a vertical slot. The length of the slot governs the degree of adjustability.
- Fastener adjusted ties allow for the vertical adjustment of the tie at the fastener location during the construction of the outer wythe.



Slotted Tie

Repair Connectors: These systems are primarily used to provide ties in areas where ties were not installed during original construction, to replace existing ties, to replace failed masonry header units, to upgrade older wall systems to current code levels, or to attach new veneers over existing facades. Typically, they consist of either a mechanical expansion system, a screw system, or an epoxy adhesive system. Each type is designed to perform a particular task. Prior to their use the designer should consult with the system manufacturer to assure their proper selection and use.

Tie Strength
Historically, building codes and construction standards prescribe minimum tie size and maximum tie spacing limits to control tie loading and deformations. This data has been derived empirically from the past performance of traditional unit ties and joint reinforcement. With the increasing use of adjustable ties, however, some concern regarding tie strength and deformation has surfaced. Depending on the adjustable tie's configuration, deflections can become quite large as vertical adjustment eccentricities are increased.

Tie loads and deformations are a function of:
- tie spacing;
- tie stiffness;
- relative stiffness between the veneer material and the back-up materials;
- location of wall openings;
- cavity width;
- support conditions of the facing and back-up materials; and
- applied loads such as seismic and wind loads.

It is generally recommended that the frequency of wall ties should be increased:
- around wall openings;
- at wall perimeter conditions, such as at corners and movement joints; and
- at the tops of cavities such as along parapet walls and below shelf angles.

These areas typically experience increased levels of lateral stress and require special consideration when determining wall tie frequency and strength.

A design professional, in consultation with the tie system manufacturer, should carefully consider all of these factors in order to properly select the appropriate type, quantity and strength of tie required to perform the necessary task.

Materials and Corrosion Resistance
Use of thinner masonry walls has contributed to the need for masonry wall ties to better resist the effects of corrosion. Typically, wall ties are available in one of three available corrosion-resistant finishes: mill galvanized steel, hot-dip galvanized steel and stainless steel. Other finishes such as fusion-bonded epoxy coatings and hard-drawn copper cladding are also available but are not as commonly used due to their higher costs.

Zinc galvanizing, using either the mill or hot-dip methods, has been the most popular and economical method of protecting connectors. Zinc acts as a barrier, becoming the sacrificial material which is consumed before the steel is attacked. Generally, the thicker the zinc coating is, the longer its protective life will be.

Mill galvanizing takes place after steel wire or sheets have been processed to their specified dimensions and prior to the fabrication of the tie itself. A zinc coating is applied in a variety of specified thicknesses to provide the required level of corrosive protection. As the coated steel wires and sheets are bent to form the desired shape, however, deformations in the coating may occur, weakening the integrity of the corrosive protection.

Hot-dip galvanizing is performed by dipping the completely fabricated tie assembly into a molten zinc bath until the specified amount of zinc is bonded to the base metal. Hot-dip galvanized coatings are typically thicker than mill galvanized coatings and should provide a greater level of corrosive protection.

Zinc galvanizing has lately been criticized for not providing adequate levels of protection. Investigations conducted by the National Research Council of Canada suggest that tie corrosion typically occurs more quickly wherever moisture is retained for long periods of time. This can occur at under-tie mortar droppings, within the mortar joint and within wet cavity insulation. Tie durability under these wet conditions significantly decreased below levels generally considered acceptable, despite having been protected with currently recommended zinc coatings.

Stainless steel ties are commonly used in corrosive environments or where a building's life expectancy dictates a greater level of corrosive protection. They are typically fabricated from one of the austenitic stainless steels conforming to ASTM A167. Generally they offer excellent protection over long periods of time under extreme conditions, unless combined with carbon- or galvanized-steel components, in which case the potential for corrosion is increased.

Summary
This ARRISCRAFT•NOTE is the first in a series of two technical papers dealing with issues relative to connectors used in masonry wall construction. It is primarily concerned with the types of wall ties used in multi-wythe unit masonry or unit masonry veneer construction.

Decisions regarding tie spacing, size, type, material and finish must be based on individual project conditions, performance requirements and safety factors. Minimum recommendations required by building codes and construction standards may not be adequate in every instance and should not be substituted for engineering judgement or investigation.

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 judgement 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

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Introduction
This ARRISCRAFT•NOTE is the second in a series of technical papers discussing connectors used in wall construction. Criteria relative to the selection of dimension stone anchoring systems will form the basis of discussion for this paper. Part I previously discussed criteria relative to selecting an appropriate wall tie for unit masonry.

Stone anchors are typically required when installing slab-type dimension stone panels having a bed depth less than the minimum acceptable bed depth for unit masonry construction.

By definition, a stone anchor is, *"…a metal shape inserted into a slot or hole in the stone that provides for the transfer of loads from the stone to the building structure, either directly or through an intermediate structure.*" (ASTM C119). They are intended to resist lateral forces, such as wind or seismic loads, but are not designed to carry the weight of the stone. Support steel, on the other hand, is a device expected to bear the weight of the stone. Anchors and support steel members together form a stone anchoring system.

Anchors and support steel may be combined to form a "*combined anchor*". In such cases the support steel members have anchoring members incorporated as part of their design to accommodate both lateral and gravity loads.

Selecting the proper stone anchoring system is dependant upon a variety of project specific factors, including:

- the building's life expectancy;
- type and relative stiffness of the structural back-up;
- wind and seismic design loads;
- exposure to moisture;
- cavity width;
- ease of installation; and
- the nature of the adjacent wall materials.

These considerations, combined with issues of availability and cost, will determine the exact type, size and finish of the anchoring system required.

To assist designers with understanding and designing stone anchoring systems the American Society for Testing and Materials has published ASTM C1242, <u>Standard Guide for Design, Selection, and Installation of Exterior Dimension Stone Anchors and Anchoring Systems.</u> This standard does not provide specific solutions to specific design problems, but rather sets forth basic requirements for the design of dimension stone anchoring systems. It also could serve as a practical checklist to ensure each requirement has been considered.

Selecting A Suitable Anchoring System
Prior to the actual selection of the anchoring system, the designer needs to establish the following factors:

- the physical characteristic of the stone;
- the design loads and necessary safety factors;
- the applicable wind and seismic loads; and
- the anticipated extent of building dimensional changes resulting from:
    - wind-load sway;
    - thermal expansion and contraction;
    - elastic deformation;
    - seismic movement;
    - creep; and
    - shrinkage.

Combined with other design considerations such as the configuration of the windows, flashing, weepholes, and insulation, these factors will help determine the size and the thickness of the stone panels to be used and the type of back-up system to which the panels should be attached.

Consulting with cladding design engineers may be prudent when special skills or the need for expertise beyond that which exists on the part of the building designer are deemed necessary. Whether such additional skills are required needs to be determined at an early stage based upon one or more of the following: knowledge of the performance record of the contemplated systems; materials or connections; complexity of the cladding and/or connection system; unusual or extreme loading conditions; unusual frames or structural configuration; and requirements of the applicable building code. Retaining a cladding engineer, however, will add substantial cost to the project and should only be used if deemed absolutely necessary.

Rules of Thumb: Some general rules to follow when determining a stone anchoring system include;

- make connections simple using the fewest number of components possible;
- limit the number of different types of connections;
- design connections to be adjustable in order to best accommodate construction tolerances;

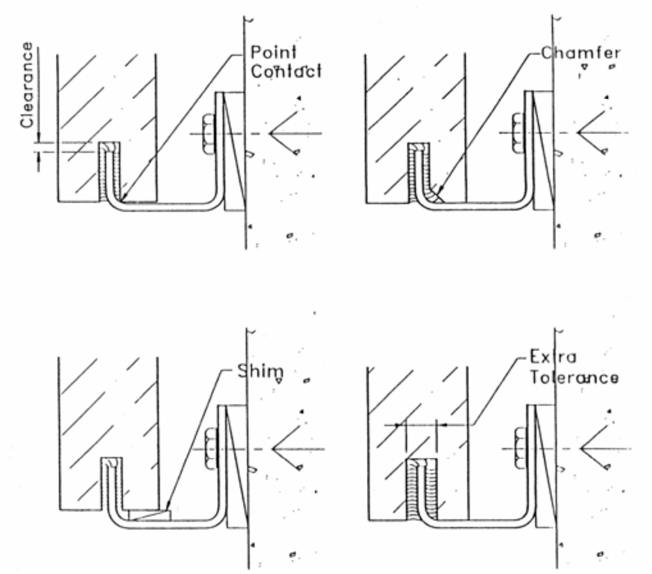
- distribute the weight of each stone panel over no more than two supports in order to simplify design calculations;
- ensure connection locations are easily accessible for installation. Avoid wherever possible the need for “blind” anchors; and
- design and arrange components in such a manner as to avoid trapping moisture.

Basic Design Criteria
A minimum of four anchors per stone is recommended, spaced according to load requirements, although the actual selection of size, number and location should be determined from analysis and testing.

The depth of the kerf or hole and the length of the embedded portion of the anchor are critical factors to be considered. The kerf or hole should be as shallow as possible but still deep enough to ensure that the anchor will not disengage as a result of building movement, anchor distortion, or joint enlargement.

ASTM C1242 recommends minimum placement and embedment criteria relative to the stone’s thickness and anchor size.

It is critical when detailing anchor connections that accommodations are made to avoid or limit the effects of point loading. Point loading can damage the kerf or hole and compromise the performance of the connection. Providing extra tolerance within the hole or kerf, shimming or chamfering the kerf edge, and using the strap anchors of sufficient strength to resist distortion under load will all contribute to avoiding problems.



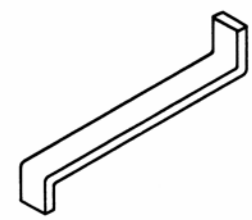
Point Loading Prevention

Kerf or holes should be filled with a non-staining sealant to preclude water entrapment within the hole or slot, which could result in staining or stone fracture if allowed to freeze. The kerf or hole sealant will also cushion the stone and in some cases assist with load distribution between the anchor and the stone. Kerf or hole sealants are separate from joint sealants and should not be allowed to come into direct contact with one another in order to avoid interactive sealant failures.

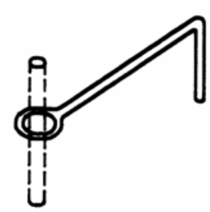
Anchor Types
Anchors can be categorized, respective of their geometry and application, into the following types:
- strap and Kerf anchors;
- rod anchor and dowels;
- tooled rod anchors;
- adhesive embedded anchors; and
- combined anchors.

Wire anchors are also available but are typically only used in interior applications and low-rise buildings where design loads and performance are limited to the reduced capacity of this type of anchor.

Strap and Kerf Anchors: are flat metal bars designed to fit into a slot or kerf cut into the edge of the stone, where the portion of the anchor inserted into the kerf applies a load to the kerf walls. Strap anchors must be strong enough to maintain their designed shape under load.

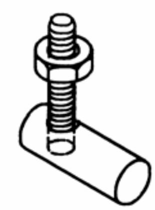


Strap Anchor



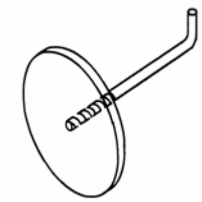
Rod Anchor and Dowels: are round metal bars designed to fit into holes previously drilled into the stone and will function until the shear capacity of the stone at the drilled hole is exceeded.

Tooled Rod Anchors: are designed to fit into specially shaped slots or holes in the stone. Most work with a wedging action and are designed to resist pull-out. Disc anchors and rod-and-plug anchors are both included in this category.



Rod-and-Plug Anchor

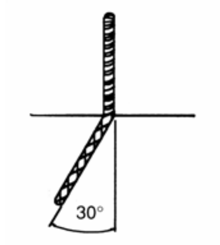
Rod-and-Plug anchors consist of a threaded rod designed to be screwed into a tapped plug that has been inserted into a round hole in the stone.



Disc Anchor

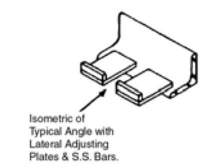
Disc anchors are a type of rod anchor that has a round, square of rectangular plate attached perpendicular to the axis of the rod. The plate is embedded into a slot in the stone, and the threaded end of the rod is then attached to the structural back-up structure.

Adhesive Embedded Anchors: are smooth, threaded or deformed rods that are placed at an angle into epoxy- or polyester resin filled holes in the stone. Pull-out strength of these connections should be tested and in all cases these tests should be conducted prior to the application of the adhesive. The integrity of these connections should be calculated and tested without crediting the quality of the adhesive. It is preferable to use this type of anchor in pairs with the angled ends opposing one another to develop the mechanical anchorage required to support the panels.



Bent Rod

Combined Anchors: are anchors which include additional members to provide for gravity support and lateral anchorage. They are, in fact, the most common type of anchor used and are formed of metal extrusions, bar, and gauge stock materials.



Combined Anchor

For example, bottom edge anchors may be combined with a steel support member, such as a steel angle, to provide gravity support. A dowel is secured to the angle and extends up into a round hole drilled into the bottom edge of the stone. These anchors could also be used as intermediate connectors between stone panels. As such, the dowel is located through a hole in the angle and extends both up into the bottom of the supported stone and down into the top edge of the stone below to act as a lateral support.

Corrosion Resistance

Unlike masonry wall ties stone anchors coming into direct contact with stone should be fabricated from Series 300 stainless steel conforming to ASTM A167. Combined anchors may contain other materials provided the anchor portion is stainless steel.

Support steel need not be stainless steel. Hot-formed steel plates or angles will perform adequately provided they have been zinc-coated, preferably using the hot-dipped method. Scratches or welds should subsequently be protected with the application of a zinc-rich paint.

Other Related Factors

ASTM C1242 describes in substantial detail many additional requirements relative to joint sealant selection, back-up structure types, and issues related to wall infiltration. These are not discussed here as they fall outside the scope of this particular discussion. Designers, however, should consider all of these factors when designing a stone cladding system.

During the preparation of construction documents, the designer should clearly stipulate drawing requirements, establish and monitor tolerances. These may require the involvement of a cladding engineer.

Shop Drawing requirements should detail all parts of the work required including material types, thicknesses, finishes, and other pertinent information dealing with fabrication, anchorage and erection of the stone panels. They should indicate any contiguous materials assemblies provided by others.

Tolerances should be clearly specified. The erection contractor should be required to progressively examine the construction to which the stone work attaches or adjoins to ensure performance with established tolerances. Recommended erection tolerances are listed in ASTM C1242.

Summary

This ARRISCRAFT•NOTE is the second in a series of two technical papers dealing with connectors used in wall construction. It is primarily concerned with the types of anchoring systems used to secure stone cladding panels.

Decisions regarding anchor spacing, size, type, material and finish must be based on individual project conditions, performance requirements and safety factors. Minimum recommendations required by building codes and construction standards may not be adequate in every instance and should not be substituted for engineering judgement or investigation.

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.

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