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 dependent 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, Standard Guide for Design, Selection, and Installation of Exterior Dimension Stone Anchors and Anchoring Systems. 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

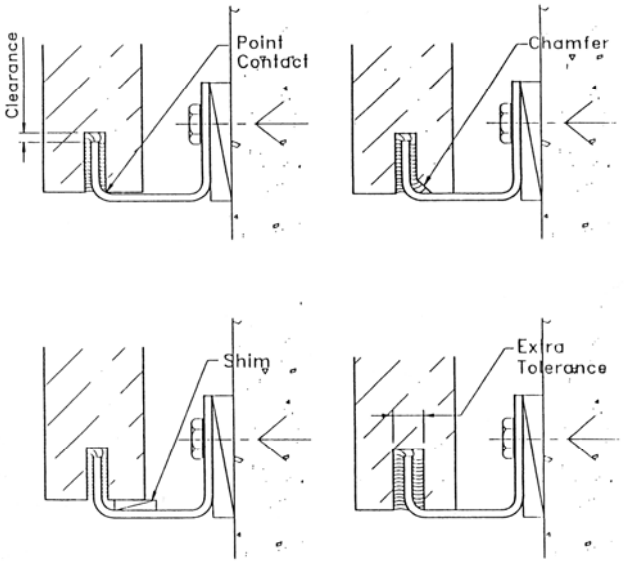
A minimum of four anchors per stone is recommended, spaced according to load requirements, although the actual

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.

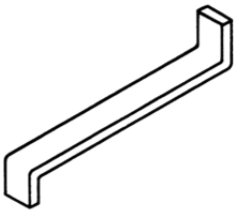
Anchor Types

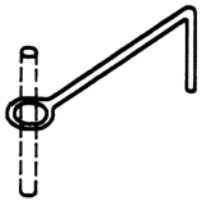
Anchors can be categorized, respective of their geometry and application, into the following types:

- 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.

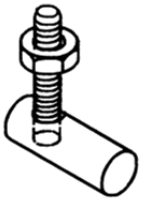
Strap and Kerf Anchors: are flat metal bars designed to fit into a slot or kerf cut into the edge of the stone, where the portion of the anchor inserted into the kerf applies a load to the kerf walls. Strap anchors must be strong enough to maintain their designed shape under load.





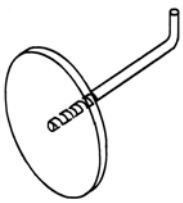
Rod Anchor and Dowels: are round metal bars designed to fit into holes previously drilled into the stone and will function until the shear capacity of the stone at the drilled hole is exceeded.

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

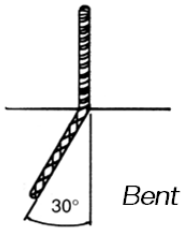
Rod-and-Plug anchors consist of a threaded rod designed to be screwed into a tapped plug that has been inserted into a round hole in the stone.



Disc Anchor

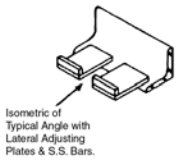
Disc anchors are a type of rod anchor that has a round, square of rectangular plate attached perpendicular to the axis of the rod. The plate is embedded into a slot in the stone, and the threaded end of the rod is then attached to the structural back-up structure.

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.

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

1. American Society for testing and Materials, ASTM C1242-96b, Standard Guide for Design, Selection, and Installation of Exterior Dimension Stone Anchors and Anchoring Systems, 1997.
2. Donaldson, Barry (ED.), New Stone Technology, Design and Construction for Exterior Wall Systems, American Society for Testing and Materials, 1988.
3. Hooker Kenneth A., Dimension Stone Anchoring Guide, Aberdeen's Magazine of Masonry Construction, May 1994; pp. 208-213.
4. Indiana Limestone Institute of America, Inc., Indiana Limestone Handbook, 19th Edition, 1992
5. Marble Institute of America, Inc., Dimension Stone Design Manual, 1997

Arriscraft

P.O. Box 3190
875 Speedsville Road
Cambridge, Ontario
Canada N3H 4S8
Toll Free: (800) 265-8123
Telephone: (519) 653-3275
Fax: (519) 653-1337
E-mail: solutions@arriscraft.com
Web: www.arriscraft.com