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Journal

Preventing and Treating Distress in Brick Veneer Cavity Walls

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Masonry construction is one of the oldest methods of creating built structures. However, the brick wall has changed considerably since the first fired clay bricks were laid nearly 8,000 years ago. To address problems and considerations with modern brick masonry, it's important to understand the components of the wall assembly, how they behave, and what can go wrong.

Today's complex brick cavity walls share little in common with the solid masonry construction of Romanesque church towers or early load-bearing high-rises, with their thick, stout walls. With multiple layers, or *wythes*, of brick bonded together, these historic masonry walls relied on the unified structural capacity of the wall thickness to withstand horizontal and vertical forces and to provide weather protection.

In contrast, modern brick veneer cavity walls anchor a single wythe of face brick across an air space, typically two to four inches wide, to a back-up material. Part of a drainage system that includes flashings, drip edges, and weep holes, the air space creates a pathway for moisture to exit the wall assembly, while a steel, concrete, or masonry back-up provides structural support.

Long, vertical cracks at building corners may indicate underlying structural distress.

What may seem on the outside to be a wall composed of a single material – clay brick – is actually a composite wall system, with materials ranging from steel and concrete to flexible flashings and sealant, in addition to traditional brick-and-mortar elements. How and where these materials come together, and why they behave the way they do, is of critical importance to the weather protection, integrity, and longevity of the wall assembly.

As modern masonry construction has grown increasingly complex, so too has the design, detailing, and installation of brick cavity walls become more demanding. Where once a skilled mason was all it took to achieve a durable exterior wall, proper construction now demands the efforts of multiple tradespeople working in collaboration with the design professional to achieve a water-tight, structurally stable, aesthetically appealing masonry exterior. Prevention of water infiltration, structural failure, and other woes by means of appropriate design and meticulous workmanship is the ideal, but for existing buildings, the mission becomes timely and accurate identification of emerging problems, with repair strategies that provide lasting solutions.

Design Basics

As reinforced concrete and steel framing have eliminated the need for

Erin L. Kesegi, AIA, Project Architect, applies her expertise in building envelope remediation to addressing underlying causes of brick masonry distress. Project Manager Robert A. Marsoli, Jr. provides engineering services to resolve structural concerns for a range of building types, including brick masonry construction.

load-bearing masonry, building design in the twentieth and twenty-first centuries has evolved new approaches to waterproofing protection. Early brick walls relied on the mass and depth of the masonry to absorb rainwater and ambient moisture and to release it back into the atmosphere. Given the nominal thickness of modern brick veneers, the mass of masonry is insufficient to absorb and release environmental moisture without allowing water penetration into the building interior. Therefore, cavity wall design provides for a space between the back of the brick veneer and the face of the back-up material, so that water that breaches the brick exterior can drain out of the wall system without reaching the building interior.

Flashing System and Waterproofing

Where transitions must exist between the brick veneer and the back-up, such as at shelf angles, lintels, and the base of the wall, *flashing*, a flexible, impermeable material, is used to collect water and drain it to the exterior. Serving both to direct water and protect the brick masonry from moisture damage, the flashing is in turn protected by counter-flashings, which are attached to or directly laid into the back-up. At the face of the wall, *drip edges*, or downward bends in rigid flashings, encourage water to form droplets that fall away from the wall surface, rather than travel back up under the flashing and into the wall assembly.

Copper, lead-coated copper, and stainless steel are the traditional materials for flashings, and they remain the most durable and reliable options. However, these materials are expensive, so flashing now tends to be composed of flexible plastics, fabric, and composite metals. Given the projected lifespan of a modern wall assembly, it's best to avoid materials that degrade quickly, such as polyvinylchloride (PVC), which may last as few as five years.

Water collected by the flashings is drained to the exterior by means of *weeps*. While open head joints in the brick course above the flashings provide a simple, effective weep system, vents, screens, and other inserts may be used to disguise the open joints and prevent insect ingress.

Lateral Support

Masonry anchors secure the wall assembly to the building structure, while *masonry ties* connect multiple wythes of masonry together or join a masonry veneer to a back-up wall composed of another material, such as concrete

Typical Masonry Cavity Wall

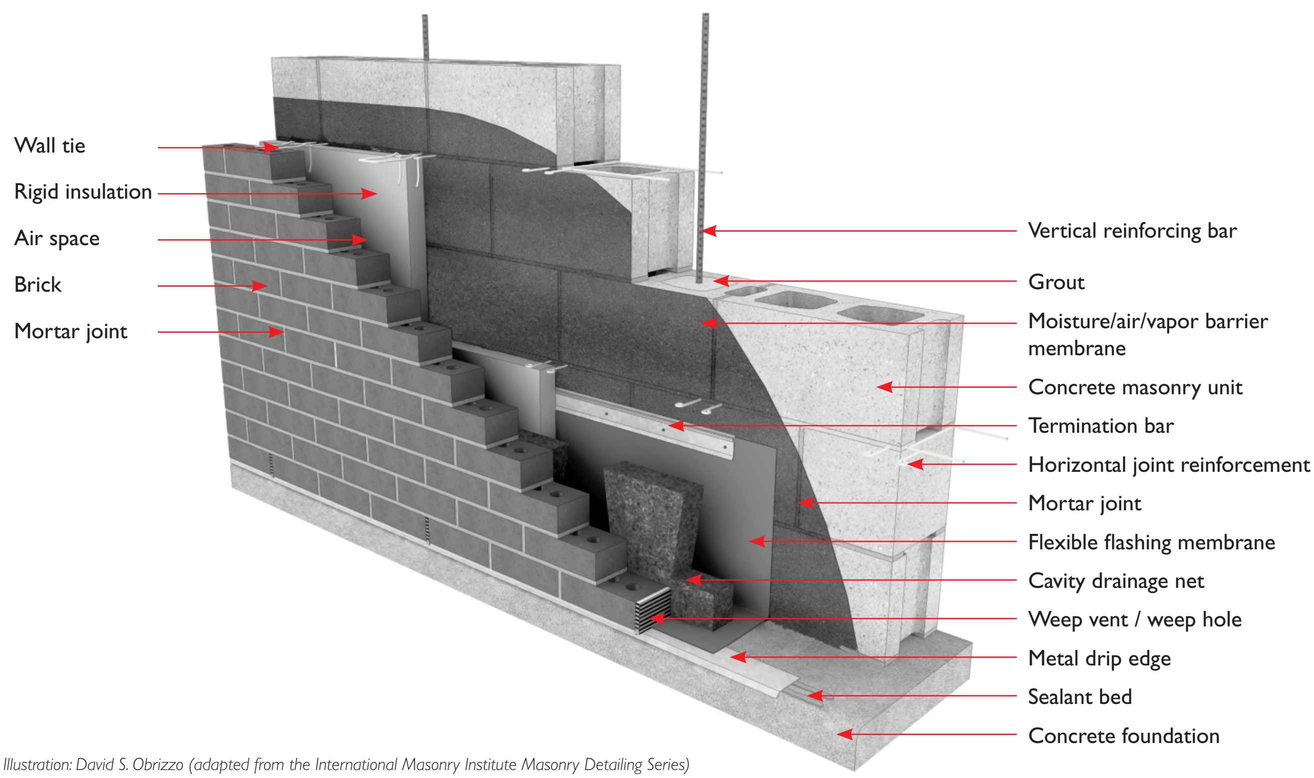

Illustration: David S. Obrizzo (adapted from the International Masonry Institute Masonry Detailing Series) masonry units (CMU) or metal studs with sheathing. All of the metal accessories for a masonry cavity wall should be stainless steel and spaced at appropriate intervals, as determined by building codes, industry standards, and the design professional.

To control shrinkage cracks in masonry, as well as to tie multiple wythes of masonry together and to anchor masonry veneers, *horizontal joint reinforcement* is incorporated into the exterior wall system. Two or more longitudinal wires with perpendicular (ladder type) or angled (truss type) cross wires are laid in the mortar joint, with the longitudinal wires parallel to the face of the wall.

Provisions for Movement

Building materials expand or contract when exposed to external stresses, such as changes in temperature (thermal movement), moisture/humidity (moisture movement), dead and live loads and external lateral forces (elastic deformation/creep). As brick draws in moisture from its environment, it will increase in size over an extended period of time. Most of the expansion typically occurs in the first few months after the brick is fired but continues at a lower rate over the following years.

Another main contributor to movement of brick is thermal expansion and contraction. Because both thermal and moisture volume changes are related to the height of the wall assembly, their cumulative effect can be significant, particularly over tall sections of veneer.

Just as brick expands over time, concrete tends to shrink. As a composite wall system that often incorporates both of these materials, a brick masonry cavity wall must accommodate these tendencies. Typically, provision for movement is achieved through horizontal and vertical expansion joints and shelf angles, along with adjustable veneer anchors that allow the two materials to move differentially within their planes, while still providing anchorage to resist out-of-plane forces, including wind and seismic pressures.

To accommodate vertical movement, steel *shelf angles* (also known as *relieving angles*) may be installed at intervals along the wall elevation, typically at each floor, to support the masonry above a horizontal expansion joint, allowing for vertical expansion of the brickwork. Use of shelf angles depends upon the type of structure, height of the building, size and location of windows, type of masonry anchorage, and a variety of other factors, including building code requirements.

Along with shelf angles, vertical and horizontal *expansion joints* are used to separate the masonry wall into segments and thereby prevent cracking. As dissimilar materials in the assembly change in response to temperature, moisture expansion, elastic deformation, settlement, and creep, each will move according to its own tendencies. Horizontal expansion joints are particularly important for masonry veneers attached to a reinforced concrete frame, as the concrete back-up tends to shrink while the brick tends to expand, a phenomenon known as *frame shortening*. Composed of flexible materials, expansion joints can close and stretch as building components shrink or expand.

Spacing of vertical expansion joints is determined by considering anticipated wall movement, size of the joint, and compressibility of the joint materials. Typically, expansion joints are placed near corners, where stress may be greatest, as well as at or near window and door openings, as appropriate.

Coursing and Dimensions

The appearance of brick masonry walls is characterized by the type and dimensions of the brick units, the mortar type and tooling profile of the joints, and the *coursing*, or pattern, of the brick layout. In contemporary brick cavity walls, the brick veneer is secured with metal wall ties to the back-up material. However, facade designs may incorporate false headers in the veneer to simulate traditional coursing patterns.

Brick size is standardized according to "nominal dimensions," which account not only for the size of the brick unit itself, but for the completed assembly in the wall system, including mortar joints. Bear in mind that openings, corners, and wall heights must take into account the dimensions and coursing using *brick module*, or increments based on the size of the brick.

Mortar Joints

Regardless of the type of masonry construction, all brick units are held together using *mortar*, a mixture of cement, aggregate, and water that is *buttered*, or spread, between bricks during *stacking*. There is no single best mortar type for all structures and situations, but a good maxim is to select the weakest mortar that will do the job. Mortar that is too hard does not permit movement of adjacent brick and can cause cracks and *spalls*, in which pieces of the brick face are forced off.

Different joint types provide different weathering capabilities, with concave, rodded, or v-shaped joints providing the best durability and water penetration resistance. Struck, raked, beaded, or extruded tooling profiles should be used with caution, as they tend to provide poor weather protection and degrade more quickly.

Code Requirements

The detailing and structural design of masonry is dictated by the governing building code, which

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Periodic Inspection and Maintenance for Brick Masonry Walls

If properly designed and constructed, brick masonry can be highly durable and tends to demand little in the way of routine repairs. However, it is still important to conduct regular inspection of the building facade to identify emerging problems and to plan for replacement of materials approaching the end of their lifespan.

While the brick units used in the wall assembly may last upwards of a century, sills, parapets, chimneys, copings, and other elements with more severe weather exposure may have a significantly shorter service life. Mortar joints may last more than 25 years before needing repairs, whereas sealants and plastic flashings may need replacement in as few as five years.

Inspection

To evaluate the behavior of different materials in various weather conditions, inspect seasonally, noting potential problems and needed repairs. Items to look for include:

- *Masonry:* cracks, spalls, loose brick, mortar cracks, deteriorated mortar, clogged weeps, vegetative growth, deteriorated sealant, efflorescence and stains, out-of-plumb units, water penetration.
- *Flashings:* damage, open lap joints, stains, missing areas.
- *Caps / Copings / Sills:* inadequate slope, cracks, mortar hairline cracks, loose or open joints, out-of-plumb units, missing drips.

Once any of the above problems have been observed, the underlying cause should be identified and corrected, as well as any outward effects of the condition.

Cleaning

Before applying a masonry cleaning product, consult the manufacturer, as the clays, additives, shales, and coatings that compose a given brick dictate how best it should be cleaned. Proprietary cleaning products formulated for brickwork may be helpful in removing stubborn stains. Pressure washers, which may be used for wetting and rinsing, can cause irreparable damage if used at excessive pressures to apply chemicals; the lowest pressure should be used to achieve the desired result. Improper acid cleaning procedures, including insufficient wetting/rinsing and strong acid concentrations, may inadvertently lead to staining, etching, and increased moisture penetration.

Before approving a cleaning approach, test all materials and methods thoroughly.

Repair

Mortar Joint Repointing: Repointing is the process of removing damaged or deteriorated mortar to a uniform depth and replacing it with new mortar. When mortar is crumbling, cracked, or softened, repointing may be necessary to protect against water penetration.

Ideally, the original mortar composition should be replicated. If this is not possible, a mortar with a similar or slightly lower compressive strength is recommended for repointing.

The existing mortar should be removed at least to a depth that is twice the joint width, or until sound mortar is reached. To prepare the joint, dust and debris should be removed by brushing, blowing with air, and/or rinsing. Joints should be dampened, but the brickwork should absorb surface water before new mortar is placed. Mortar should be packed tightly in thin layers and tooled to match the original profile.

Both for water penetration protection and for aesthetic consistency, it is best to avoid partial repointing of a wall area. Cutting out and replacing all of the mortar joints across a given wall area or distinct visual element avoids a patchwork appearance and reduces long-term repair costs by replacing all of the suspect mortar in one go.

Sealant Replacement: Although most of the joints in a brick masonry cavity wall are filled with mortar, the intersections between brickwork and other materials, such as windows, doors, roofs, or expansion joints, are filled with sealant. Since the lifespan of sealants can range from five to twenty years, sealant deterioration is a common source of moisture intrusion. When inspecting the facade, look for sealant that is missing, deteriorated, torn, or sagging and arrange for replacement with a sealant that is compatible with the adjacent materials.

Vegetation Removal: Ivy may look fetching along the side of a building, but the ivy shoots penetrate voids in the mortar and tend to contribute to water infiltration. Rather than pull the vines from the wall, which can damage masonry, vines should be cut and allowed to dry up; they may then be removed using a stiff fiber brush and water. If the vines have damaged the mortar, repointing may be necessary.

Weep Hole Repair: Clogged weep holes may be opened by means of a dowel or stiff wire. If weep spacing is insufficient to effectively drain moisture to the exterior, new weep holes may need to be drilled. Consult a design professional before probing or drilling, as incorrectly placed weep holes may do more harm than good, and it is easy to accidentally damage concealed underlying flashing.

Brick Unit Replacement: Severely spalled or damaged brick should be replaced with units selected to match the originals in color, dimensions, and texture. After the damaged brick has been removed from the wall, all of the existing mortar should be cleared away and the surface cleaned and prepared. With the appropriate surfaces buttered with new mortar, replacement brick should be pressed into position and joints fully pointed and tooled. As with repointing, mortar for brick replacement should be selected to match the existing mortar in properties and appearance.

Flashing Installation: When an investigation reveals that flashing is missing, damaged, or improperly installed, the exterior brick veneer must be removed to install the appropriate flashing. If the problem is allowed to persist, water will continue to become trapped in the wall cavity, leading to deterioration of the assembly and, eventually, infiltration into the building interior.

Wall Tie and Anchor Retrofit: Without proper support, the exterior veneer of a cavity wall assembly is vulnerable to catastrophic collapse and failure, as it requires anchorage to the back-up to remain stable. When a wall has been constructed with insufficient ties, or where the existing connections have failed, retrofit anchors, such as helical screws, may be installed through a mortar joint and attached to the back-up substrate. Since each situation and wall assembly is different, and products vary in installation methods and limitations, it is critical to consult with a design professional and with the retrofit anchor manufacturer before attempting to repair anchorage issues.

A Note on Water-Repellent Coatings

Properly designed and constructed masonry walls provide water infiltration protection without the aid of water-repellent coatings, and, in most cases, the addition of such a product causes more problems than it solves. Water-repellent coatings are no replacement for design details that resist water penetration. However, there may be isolated instances in which a breathable coating can be used successfully, such as for masonry subject to extreme exposure. A design professional can work with the manufacturer to determine when and where a vapor-permeable water repellent product might merit consideration. ■

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often references "ACI 530 - Building Code Requirements for Masonry Structures," a consensus standard from the American Concrete Institute (ACI), the American Society of Civil Engineers (ASCE), and The Masonry Society (TMS). In addition to the standards set forth in these codes, technical publications from the Brick Industry Association (known as "Tech Notes"), are typically used when designing and detailing masonry structures.

Building codes and standards include prescriptive requirements for the attachment of the veneer to a variety of back-up materials, such as wood, metal framing, or CMU. Wind and seismic design requirements for each type of construction are typically based on "ASCE 7: Minimum Design Loads for Buildings and Other Structures" or on the governing building code, which often references ASCE 7.

Lateral displacement of brick veneer.

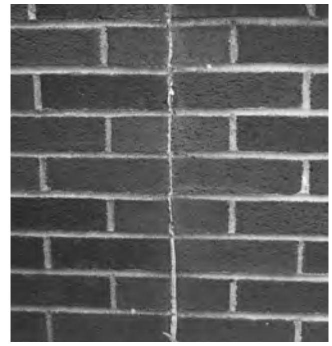
Common Problems and Their Causes

Like all building assemblies, brick masonry is not without issues inherent to the material, the type of construction, and shortcomings in the design and construction of the wall assembly. Astute observation of the early warning signs of masonry distress enables prompt remediation of the problem, which often provides a cost savings over the long term, as emerging problems are best addressed well before they become emergencies.

Corrosion of steel shelf angle.

Mortar joint failure.

Efflorescence.



Insufficient expansion joint width.

Of all issues with brick masonry construction, those resulting from water penetration are the most common.

Efflorescence

Observable as white stains or salty streaks on the surface of masonry walls, efflorescence occurs when moisture within the wall assembly leaches water-soluble salts from the mortar or masonry. The main cause of efflorescence is water infiltration, whether from poor mortar joints, cracked brick, or other sources. Also, sloppy workmanship can clog the wall cavity with excess mortar and prevent water from reaching flashings and exiting the wall. Forced to find another means of escape, trapped moisture travels through the brick, resulting in efflorescence.

Once the problem has been identified and remediated, it may be difficult or even impossible to clean away salt deposits that have bonded to the masonry surface. If moisture has reached the building interior, water damage and mold may also need to be addressed.

Freeze-Thaw Damage

In temperate climates, water that penetrates masonry walls may lead to structural damage, as low temperatures cause trapped moisture to freeze and expand, applying pressure to the surrounding materials. Typical causes of excess water infiltration in masonry structures include mortar profiles that trap water and direct it into the veneer, poor flashing details around openings or penetrations that allow moisture into the wall system, and roof leaks that travel down into the wall assembly.

Condensation

In some climates and conditions, differences in humidity and air pressure between inside and outside can drive water vapor into the wall, where it may condense and lead to moisture-related problems. Design provisions to reduce air infiltration, vapor permeability, and thermal bridging can help to control condensation.

Flashing Problems

Flashing detailing is particularly important at intersections and terminations. Where the segments of continuous flashing intersect, they should be lapped and sealed using a method appropriate to the material. Discontinuous flashing, as at a window or door opening, should extend beyond the end of the lintel, with the ends turned up to prevent water from running back into the wall from the edge of the flashing.

Plastics, composites, and thin metal cannot be formed into a drip edge. Instead, these materials should be terminated within the veneer to prevent degradation or *drooling*, in which heat and ultraviolet radiation cause rubberized flashing to soften and exude from the joint.

Restricted Movement

When expansion joints are too narrow or spaced too far apart, there is insufficient accommodation for brick expansion, forcing sealant out of the joint and eventually leading to cracks and failure of the surrounding masonry. Failure to include expansion joints at building corners is a common cause of distress; as the masonry expands along the plane of the wall, the brick on each side of the corner comes together, leading to long vertical cracks and/or brick displacement at building corners.

Structural Issues

Causes of structural distress in brick masonry cavity walls are often related to the corrosion of embedded steel elements, which can lead to cracks and displacement. As water penetration causes steel lintels, reinforcement, anchors, ties, and accessories to corrode, they expand, exerting tremendous pressure on the surrounding facade, which can sometimes fail dramatically as a result.

Insufficient or failed anchorage of the veneer to the back-up can lead to bowing and/or lateral displacement of the masonry.

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representative projects

Brick Masonry Cavity Walls

To develop long-lasting rehabilitation solutions for brick masonry wall systems, our design professionals evaluate existing conditions and identify underlying causes of deterioration and failure. Through engineering analysis, evidence-based empirical design, and detail-oriented project administration, Hoffmann Architects applies nearly 40 years of professional practice to the prevention and resolution of masonry distress.

Hoffmann Architects' recent projects involving investigation and remediation of brick masonry facades include:

Southern Connecticut State University, Residence Halls
New Haven, Connecticut
Masonry Condition Survey and Leak Investigation

Episcopal High School
Stewart Student Center
Alexandria, Virginia
Masonry Facade Consultation

Princeton University
Lawrence Apartments
Princeton, New Jersey
Building Envelope Study and Repair

Aetna Headquarters
Rogers Building
Hartford, Connecticut
Masonry Investigation and Repair

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Newark, New Jersey
Facade Investigation, Repair, and Replacement

Schering Plough Headquarters
Summit, New Jersey
Facade Reconstruction

Albright College
Gingrich Library
Reading, Pennsylvania
Building Envelope Investigation

Stamford Corners
Stamford, Connecticut
Facade Rehabilitation

Yonkers Employment Center and Westchester Department of Health
20 South Broadway
Yonkers, New York
Masonry Exterior Wall Investigation

The Ellington Apartments
Washington, District of Columbia
Facade Investigation and Repair

Fairfield Warde High School
Fairfield, Connecticut
Facade Investigation and Repair

State University of New York
Farmingdale State College
Whitman Hall
Farmingdale, New York
Building Envelope Rehabilitation

Chase Collegiate School, Saint Margaret's Hall in Waterbury, Connecticut. *Portico and Masonry Rehabilitation.*

Edge Fund Advisors, 4 New York Plaza in New York, New York. *Facade Investigation and Rehabilitation.*

Barnard College
Plimpton Hall
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Saint Joseph Church
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Facade Investigation and Repair

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Sealant alone cannot resolve masonry distress.

Readily identifiable by their tapering shape, deflection cracks may occur at steel shelf angles attached to spandrel beams that deflect. Uneven settlement in the foundation due to unstable soil conditions may also be the cause of stress cracking in masonry walls, as one portion of the structure settles more than another.

Addressing the Challenges of Modern Masonry Facades

Popular for their superior resistance to rain penetration, sound transmission, fire, and heat transfer—and for their cost-effectiveness—masonry cavity walls are ubiquitous across all building styles and types. Although cavity walls did not even feature in building codes until at least the late 1930s, the extensive testing, research, and field performance data that have emerged since then have refined brick cavity walls to the degree that the Brick Industry Association calls them "the premier masonry wall system."

Like all building assemblies, even the dependable masonry cavity wall can succumb to leaks, cracks, stains, and deterioration if not correctly designed, built, and maintained. To treat persistent problems, and, better, to prevent new ones from emerging, it is important to understand the basics of brick cavity wall construction and to recognize the symptoms of distress and failure. By proactively addressing incipient design, detailing, workmanship, and age-related problems, building owners and managers can prolong the life of the building and avoid the expense and disruption of major rehabilitation. ■

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