Detailing Specific Cladding Requirements for Mid-Rise Wood-Framed Buildings

[This presentation was originally developed for the 2020 national convention of the International Institute for Building Enclosure Consultants (IIBEC) and will be published in those proceedings]

Presented by Warren R. French, P.E., RBEC, F-IIBEC

"The Wood Products Council" is a Registered Provider with The American Institute of Architects Continuing Education Systems (AIA/CES), Provider #G516.

Credit(s) earned on completion of this course will be reported to AIA CES for AIA members. Certificates of Completion for both AIA members and non-AIA members are available upon request.

This course is registered with AIA CES for continuing professional education. As such, it does not include content that may be deemed or construed to be an approval or endorsement by the AIA of any material of construction or any method or manner of handling, using, distributing, or dealing in any material or product.

Questions related to specific materials, methods, and services will be addressed at the conclusion of this presentation.

Course Description

Mid-rise wood-frame buildings have become ubiquitous in modern construction and getting taller all the time – with five stories now common across the U.S. However, they are not without challenges. One aspect that requires unique consideration and detailing is the potential cumulative effect of wood shrinkage and elastic column shortening of the structure. In particular, the effect of shrinkage on the cladding system and its attachment to the wood-frame structure must be accounted for with proper detailing to achieve long-term cladding durability. This presentation will explore the design and attachment of a number of exterior cladding systems on multi-story wood-frame buildings, including Portland cement plaster (stucco), exterior insulation and finish systems (EIFS), metal panels, and fiber-cement lap siding.

Learning Objectives

1. Discuss the composition and behavior of wood framing members in order to understand how moisture and wood interact, and identify why shrinkage occurs.

2. Explain methods of calculating expected shrinkage in multi-story wood-frame buildings.

3. Highlight best practice details for cladding system attachment to wood-frame structures, emphasizing the need to accommodate cumulative shrinkage.

4. Review considerations and solutions associated with long-term durability and performance of a number of cladding systems in Texas climates.

(Not to get too "philosophical" about things, but…)

Aristotle (384 – 322 BC) – on "Final Cause":

"A complete explanation of an object will involve knowledge of how it came to be (efficient cause), what material it consists of (material cause), how that material is structured (formal cause), and the specific behaviors associated with the type of thing it is (final cause)."

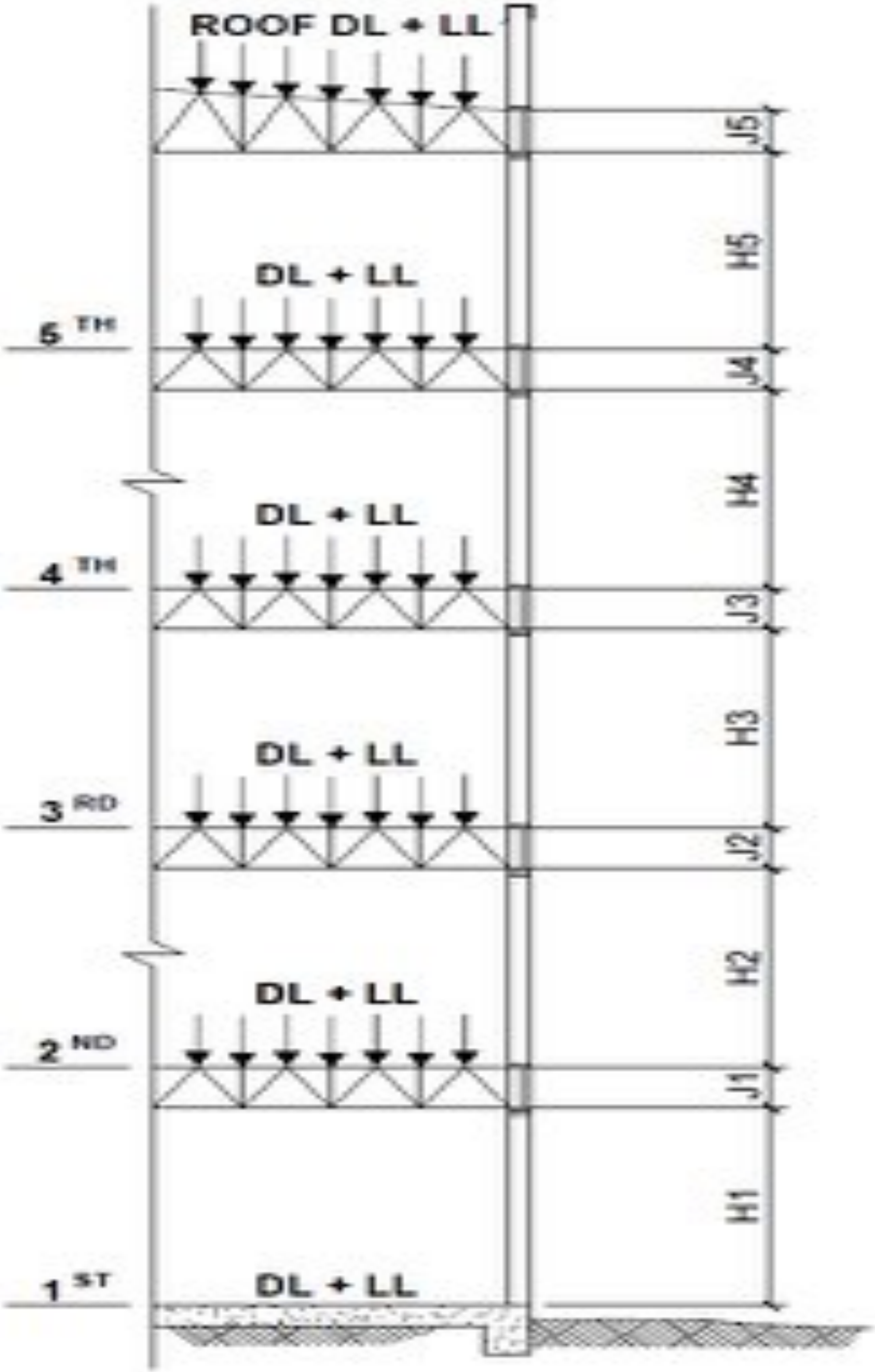
Falcon, Andrea (2015), "Aristotle on Causality 2," The Stanford Encyclopedia of Philosophy, ISSN 1095-5054.

INTRODUCTION

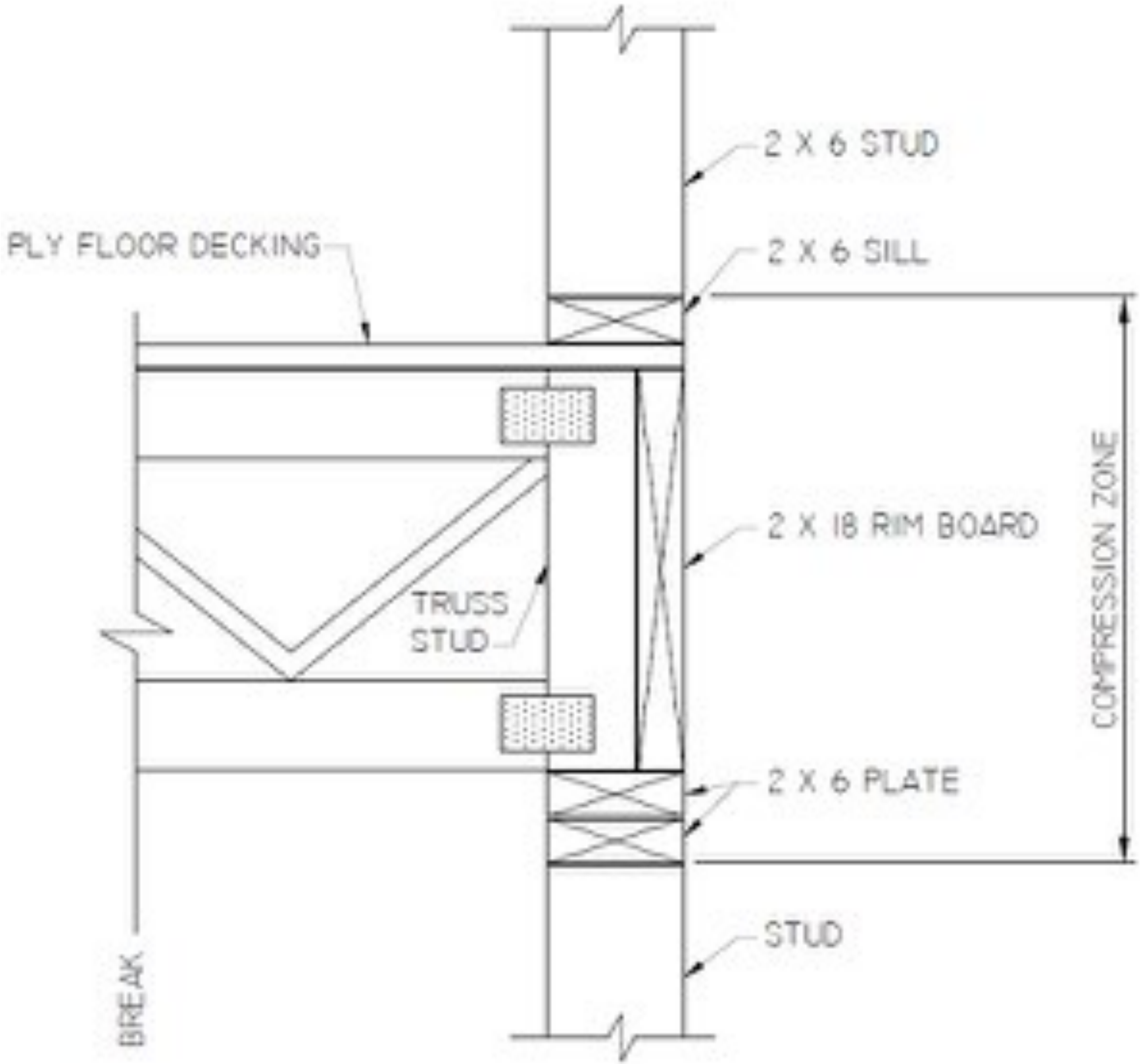
- **Multi-story, wood-framed buildings have become ubiquitous in modern construction.**
- **It is widely recognized that detailing for these types of buildings are *different* from one-story and two-story buildings.**
- **Specifically, accommodating changes in building height during and after construction should be part of any "good" design.**
- **The need is often seen for plumbing and mechanical installations, but detailing for cladding is often lacking.**

<u>INTRODUCTION (con't.)</u>

- **Sequencing and scheduling often result in an early dry-in, with the roofing and cladding systems in place very quickly.**
- **Afterwards, typical <u>Dead Loads</u> are *increased* by normal installation of mechanical, plumbing, drywall, cabinets, fixtures, ceilings, and flooring.**
- **Ultimately, typical <u>Live Loads</u> are imposed, including movable furniture, people, etc.**



Typical conceptual schematic depicting dead loads and live loads transferred to exterior load bearing walls from each elevated floor and from the roof level. These are cumulative at the lower floors.



Typical conceptual assembly at floor line, showing wood members with loads applied perpendicular to the grain, resulting in a "zone" of compression subject to moisture shrinkage.

Prior Resources:

- “Shrinkage Calculations for Multi-Story Wood Frame Construction, Tech Note No. 10”, Western Wood Products Association (WWPA), Portland, OR, November 2002.

- McLain, P.E., Richard, and Steimle, P.E., Doug, “Accommodating Shrinkage in Multi-Story Wood-Frame Structures”, Wood-Works™, WW-WSP-10, Washington, D.C., 2017.

- 2015 International Building Code (IBC), Section 2304.3.3., 2015.

WoodWorks™
WOOD PRODUCTS COUNCIL

Accommodating Shrinkage in Multi-Story Wood-Frame Structures

Richard McLain, MS, PE, SE, Senior Technical Director – Tall Wood, WoodWorks • Doug Steimle, PE, Principal, Schaefer

In wood-frame buildings of three or more stories, cumulative shrinkage can be significant and have an impact on the function and performance of finishes, openings, mechanical/electrical/plumbing (MEP) systems, and structural connections. However, as more designers look to wood-frame construction to improve the cost and sustainability of their mid-rise projects, many have learned that accommodating wood shrinkage is actually very straightforward.

Wood is hygroscopic, meaning it has the ability to absorb and release moisture. As this occurs, it also has the potential to change dimensionally. Knowing how and where wood shrinks and swells helps designers detail their buildings to minimize related effects.

Wood shrinkage occurs perpendicular to grain, meaning that a solid sawn wood stud or floor joist will shrink in its cross-section dimensions (width and depth). Longitudinal shrinkage is negligible, meaning the length of a stud or floor joist will essentially remain unchanged. In multi-story buildings, wood shrinkage is therefore concentrated at the wall plates, floor and roof joists, and rim boards. Depending on the materials and details used at floor-to-wall and roof-to-wall intersections, shrinkage in light-frame wood construction can range from 0.05 inches to 0.5 inches per level.

This publication will describe procedures for estimating wood shrinkage and provide detailing options that minimize its effects on building performance.

The Brooklyn Riverside
Jacksonville, Florida
Architect: Dwell Design Studio
Structural Engineer: M2 Structural Engineering

Photo: Pollack Shores, Matrix Residential

a longitudinal cell in the wood. Water can be free water stored in the straw cavity or bound water absorbed by the straw walls. At high moisture contents, water exists in both locations. As the wood dries, the free water is released from the cell cavities before the bound water is released from

IBC®

2015

INTERNATIONAL CODES®

INTERNATIONAL Building Code®

A Member of the International Code Family®

INTERNATIONAL CODE COUNCIL®

CHAPTER 23

WOOD

User note: Code change proposals to this chapter will be considered by the IBC – Structural Code Development Committee during the 2016 (Group B) Code Development Cycle. See explanation on page iv.

SECTION 2301
GENERAL

2301.1 Scope. The provisions of this chapter shall govern the materials, design, construction and quality of wood members and their fasteners.

2301.2 General design requirements. The design of structural elements or systems, constructed partially or wholly of wood or wood-based products, shall be in accordance with one of the following methods:

1. *Allowable stress design* in accordance with Sections 2304, 2305 and 2306.
2. *Load and resistance factor design* in accordance with Sections 2304, 2305 and 2307.
3. *Conventional light-frame construction* in accordance with Sections 2304 and 2308.
4. AWC WFCM in accordance with Section 2309.
5. The design and construction of log structures in accordance with the provisions of ICC 400.

2301.3 Nominal sizes. For the purposes of this chapter, where dimensions of lumber are specified, they shall be deemed to be nominal dimensions unless specifically designated as actual dimensions (see Section 2304.2).

SECTION 2302
DEFINITIONS

2302.1 Definitions. The following terms are defined in Chapter 2:

ACCREDITATION BODY.

BRACED WALL LINE.

BRACED WALL PANEL.

COLLECTOR.

CONVENTIONAL LIGHT-FRAME CONSTRUCTION.

CRIPPLE WALL.

CROSS-LAMINATED TIMBER.

DIAPHRAGM, UNBLOCKED.

DRAG STRUT.

ENGINEERED WOOD RIM BOARD.

FIBERBOARD.

GABLE.

GRADE (LUMBER).

HARDBOARD.

NAILING, BOUNDARY.

NAILING, EDGE.

NAILING, FIELD.

NOMINAL SIZE (LUMBER).

PARTICLEBOARD.

PERFORMANCE CATEGORY.

PREFABRICATED WOOD I-JOIST.

SHEAR WALL.

Shear wall, perforated.

Shear wall segment, perforated.

STRUCTURAL COMPOSITE LUMBER.

Laminated strand lumber (LSL).

Laminated veneer lumber (LVL).

Oriented strand lumber (OSL).

Parallel strand lumber (PSL).

STRUCTURAL GLUED-LAMINATED TIMBER.

TIE-DOWN (HOLD-DOWN).

TREATED WOOD.

Fire-retardant-treated wood.

Preservative-treated wood.

WOOD SHEAR PANEL.

WOOD STRUCTURAL PANEL.

Composite panels.

Oriented strand board (OSB).

Plywood.

SECTION 2303
MINIMUM STANDARDS AND QUALITY

2303.1 General. Structural sawn lumber; end-jointed lumber; prefabricated wood I-joists; structural glued-laminated timber; wood structural panels; fiberboard sheathing (when used structurally); hardboard siding (when used structurally); particleboard; *preservative-treated wood*; structural log members; structural composite lumber; round timber poles and piles; *fire-retardant-treated wood*; hardwood plywood; wood trusses; joist hangers; nails; and staples shall conform to the applicable provisions of this section.

2303.1.1 Sawn lumber. Sawn lumber used for load-supporting purposes, including end-jointed or edge-glued lumber, machine stress-rated or machine-evaluated lumthe design of the temporary installation restraint/bracing and the permanent individual truss member restraint/bracing for all trusses with clear spans 60 feet (18 288 mm) or greater.

2303.4.1.4 Truss designer. The individual or organization responsible for the design of trusses.

2303.4.1.4.1 Truss design drawings. Where required by the *registered design professional*, the *building official* or the statutes of the jurisdiction in which the project is to be constructed, each individual truss design drawing shall bear the seal and signature of the truss designer.

Exceptions:

1. Where a cover sheet and truss index sheet are combined into a single sheet and attached to the set of truss design drawings, the single cover/truss index sheet is the only document required to be signed and sealed by the truss designer.
2. When a cover sheet and a truss index sheet are separately provided and attached to the set of truss design drawings, the cover sheet and the truss index sheet are the only documents required to be signed and sealed by the truss designer.

2303.4.2 Truss placement diagram. The truss manufacturer shall provide a truss placement diagram that identifies the proposed location for each individually designated truss and references the corresponding truss design drawing. The truss placement diagram shall be provided as part of the truss submittal package, and with the shipment of trusses delivered to the job site. Truss placement diagrams that serve only as a guide for installation and do not deviate from the *permit* submittal drawings shall not be required to bear the seal or signature of the truss designer.

2303.4.3 Truss submittal package. The truss submittal package provided by the truss manufacturer shall consist of each individual truss design drawing, the truss placement diagram, the permanent individual truss member restraint/bracing method and details and any other structural details germane to the trusses; and, as applicable, the cover/truss index sheet.

2303.4.4 Anchorage. The design for the transfer of loads and anchorage of each truss to the supporting structure is the responsibility of the *registered design professional*.

2303.4.5 Alterations to trusses. Truss members and components shall not be cut, notched, drilled, spliced or otherwise altered in any way without written concurrence and approval of a *registered design professional*. Alterations resulting in the addition of loads to any member (e.g., HVAC equipment, piping, additional roofing or insulation, etc.) shall not be permitted without verification that the truss is capable of supporting such additional loading.

2303.4.6 TPI 1 specifications. In addition to Sections 2303.4.1 through 2303.4.5, the design, manufacture and quality assurance of metal-plate-connected wood trusses shall be in accordance with TPI 1. Job-site inspections shall be in compliance with Section 110.4, as applicable.

2303.4.7 Truss quality assurance. Trusses not part of a manufacturing process in accordance with either Section 2303.4.6 or a referenced standard, which provides requirements for quality control done under the supervision of a third-party quality control agency, shall be manufactured in compliance with Sections 1704.2.5 and 1705.5, as applicable.

2303.5 Test standard for joist hangers. Joist hangers shall be in accordance with ASTM D7147.

2303.6 Nails and staples. Nails and staples shall conform to requirements of ASTM F1667. Nails used for framing and sheathing connections shall have minimum average bending yield strengths as follows: 80 kips per square inch (ksi) (551 MPa) for shank diameters larger than 0.177 inch (4.50 mm) but not larger than 0.254 inch (6.45 mm), 90 ksi (620 MPa) for shank diameters larger than 0.142 inch (3.61 mm) but not larger than 0.177 inch (4.50 mm) and 100 ksi (689 MPa) for shank diameters of at least 0.099 inch (2.51 mm) but not larger than 0.142 inch (3.61 mm).

2303.7 Shrinkage. Consideration shall be given in design to the possible effect of cross-grain dimensional changes considered vertically which may occur in lumber fabricated in a green condition.

SECTION 2304
GENERAL CONSTRUCTION REQUIREMENTS

2304.1 General. The provisions of this section apply to design methods specified in Section 2301.2.

2304.2 Size of structural members. Computations to determine the required sizes of members shall be based on the net dimensions (actual sizes) and not nominal sizes.

2304.3 Wall framing. The framing of exterior and interior walls shall be in accordance with the provisions specified in Section 2308 unless a specific design is furnished.

2304.3.1 Bottom plates. Studs shall have full bearing on a 2-inch-thick (actual $1^1/_2$-inch, 38 mm) or larger plate or sill having a width at least equal to the width of the studs.

2304.3.2 Framing over openings. Headers, double joists, trusses or other *approved* assemblies that are of adequate size to transfer loads to the vertical members shall be provided over window and door openings in load-bearing walls and partitions.

2304.3.3 Shrinkage. Wood walls and bearing partitions shall not support more than two floors and a roof unless an analysis satisfactory to the *building official* shows that shrinkage of the wood framing will not have adverse effects on the structure or any plumbing, electrical or mechanical systems or other equipment installed therein due to excessive shrinkage or differential movements caused by shrinkage. The analysis shall also show that the roof drainage system and the foregoing systems or equipment will not be adversely affected or, as an alternate, such systems shall be designed to accommodate the differential shrinkage or movements.

2304.3.3 Shrinkage. Wood walls and bearing partitions shall not support more than two floors and a roof unless an analysis satisfactory to the *building official* shows that shrinkage of the wood framing will not have adverse effects on the structure or any plumbing, electrical or mechanical systems or other equipment installed therein due to excessive shrinkage or differential movements caused by shrinkage. The analysis shall also show that the roof drainage system and the foregoing systems or equipment will not be adversely affected or, as an alternate, such systems shall be designed to accommodate the differential shrinkage or movements.

INCLUDES
International Private Sewage Disposal Code®

IPC®

2015

INTERNATIONAL CODES®

INTERNATIONAL Plumbing Code®

A Member of the International Code Family®

INTERNATIONAL CODE COUNCIL®

SECTION 305 PROTECTION OF PIPES AND PLUMBING SYSTEM COMPONENTS

305.1 Corrosion. Pipes passing through concrete or cinder walls and floors or other corrosive material shall be protected against external corrosion by a protective sheathing or wrapping or other means that will withstand any reaction from the lime and acid of concrete, cinder or other corrosive material. Sheathing or wrapping shall allow for movement including expansion and contraction of piping. The wall thickness of the material shall be not less than 0.025 inch (0.64 mm).

305.2 Stress and strain. Piping in a plumbing system shall be installed so as to prevent strains and stresses that exceed the structural strength of the pipe. Where necessary, provisions shall be made to protect piping from damage resulting from expansion, contraction and structural settlement.

305.3 Pipes through foundation walls. Any pipe that passes through a foundation wall shall be provided with a relieving arch, or a pipe sleeve pipe shall be built into the foundation wall. The sleeve shall be two pipe sizes greater than the pipe passing through the wall.

305.4 Freezing. Water, soil and waste pipes shall not be installed outside of a building, in attics or crawl spaces, concealed in outside walls, or in any other place subjected to freezing temperatures unless adequate provision is made to protect such pipes from freezing by insulation or heat or both. Exterior water supply system piping shall be installed not less than 6 inches (152 mm) below the frost line and not less than 12 inches (305 mm) below grade.

305.4.1 Sewer depth. *Building sewers* that connect to private sewage disposal systems shall be installed not less than [NUMBER] inches (mm) below finished grade at the point of septic tank connection. *Building sewers* shall be installed not less than [NUMBER] inches (mm) below grade.

305.5 Waterproofing of openings. Joints at the roof and around vent pipes shall be made water tight by the use of lead, copper, galvanized steel, aluminum, plastic or other *approved* flashings or flashing material. Exterior wall openings shall be made water tight.

305.6 Protection against physical damage. In concealed locations where piping, other than cast-iron or galvanized steel, is installed through holes or notches in studs, joists, rafters or similar members less than $1^1/_2$ inches (38 mm) from the nearest edge of the member, the pipe shall be protected by steel shield plates. Such shield plates shall have a thickness of not less than 0.0575 inch (1.463 mm) (No. 16 gage). Such plates shall cover the area of the pipe where the member is notched or bored, and shall extend not less than 2 inches (51 mm) above sole plates and below top plates.

305.7 Protection of components of plumbing system. Components of a plumbing system installed along alleyways, driveways, parking garages or other locations exposed to damage shall be recessed into the wall or otherwise protected in an *approved* manner.

SECTION 306 TRENCHING, EXCAVATION AND BACKFILL

306.1 Support of piping. Buried piping shall be supported throughout its entire length.

306.2 Trenching and bedding. Where trenches are excavated such that the bottom of the trench forms the bed for the pipe, solid and continuous load-bearing support shall be provided between joints. Bell holes, hub holes and coupling holes shall be provided at points where the pipe is joined. Such pipe shall not be supported on blocks to grade. In instances where the materials manufacturer's installation instructions are more restrictive than those prescribed by the code, the material shall be installed in accordance with the more restrictive requirement.

306.2.1 Overexcavation. Where trenches are excavated below the installation level of the pipe such that the bottom of the trench does not form the bed for the pipe, the trench shall be backfilled to the installation level of the bottom of the pipe with sand or fine gravel placed in layers not greater than 6 inches (152 mm) in depth and such backfill shall be compacted after each placement.

306.2.2 Rock removal. Where rock is encountered in trenching, the rock shall be removed to not less than 3 inches (76 mm) below the installation level of the bottom of the pipe, and the trench shall be backfilled to the installation level of the bottom of the pipe with sand tamped in place so as to provide uniform load-bearing support for the pipe between joints. The pipe, including the joints, shall not rest on rock at any point.

306.2.3 Soft load-bearing materials. If soft materials of poor load-bearing quality are found at the bottom of the trench, stabilization shall be achieved by overexcavating not less than two pipe diameters and backfilling to the installation level of the bottom of the pipe with fine gravel, crushed stone or a concrete foundation. The concrete foundation shall be bedded with sand tamped into place so as to provide uniform load-bearing support for the pipe between joints.

306.3 Backfilling. Backfill shall be free from discarded construction material and debris. Loose earth free from rocks, broken concrete and frozen chunks shall be placed in the trench in 6-inch (152 mm) layers and tamped in place until the crown of the pipe is covered by 12 inches (305 mm) of tamped earth. The backfill under and beside the pipe shall be compacted for pipe support. Backfill shall be brought up evenly on both sides of the pipe so that the pipe remains aligned. In instances where the manufacturer's instructions for materials are more restrictive than those prescribed by the code, the material shall be installed in accordance with the more restrictive requirement.

306.4 Tunneling. Where pipe is to be installed by tunneling, jacking or a combination of both, the pipe shall be protected from damage during installation and from subsequent uneven loading. Where earth tunnels are used, adequate supporting structures shall be provided to prevent future settling or caving.

305.2 Stress and strain. Piping in a plumbing system shall be installed so as to prevent strains and stresses that exceed the structural strength of the pipe. Where necessary, provisions shall be made to protect piping from damage resulting from expansion, contraction and structural settlement.


"U.S. PAT NO. 5,591,497" CSA B137.6 MADE IN USA 3107 06/25/15 04:59

TAKE AWAYS FROM CODE:

- **Design and Construction shall not support more than two stories and a roof unless an analysis satisfactory to the *building official* has been conducted (and submitted?)**
- **Must show that shrinkage will not have adverse effect on the structure or any plumbing, electrical or mechanical system or other equipment installed therein… (how will that be demonstrated?)**
- **Where in that list is the cladding system or exterior building enclosure?!!**

2304.6 Exterior wall sheathing. Wall sheathing on the outside of exterior walls, including gables, and the connection of the sheathing to framing shall be designed in accordance with the general provisions of this code and shall be capable of resisting wind pressures in accordance with Section 1609.

2304.6.1 Wood structural panel sheathing. Where wood structural panel sheathing is used as the exposed finish on the outside of exterior walls, it shall have an exterior exposure durability classification. Where wood structural panel sheathing is used elsewhere, but not as the exposed finish, it shall be of a type manufactured with exterior glue (Exposure 1 or Exterior). Wood structural panel sheathing, connections and framing spacing shall be in accordance with Table 2304.6.1 for the applicable wind speed and exposure category where used in enclosed buildings with a mean roof height not greater than 30 feet (9144 mm) and a topographic factor (K_{zt}) of 1.0.

TABLE 2304.6.1
MAXIMUM NOMINAL DESIGN WIND SPEED, V_{asd} PERMITTED FOR WOOD STRUCTURAL PANEL WALL SHEATHING USED TO RESIST WIND PRESSURES[a, b, c]

MINIMUM NAIL		MINIMUM WOOD STRUCTURAL PANEL SPAN RATING	MINIMUM NOMINAL PANEL THICKNESS (inches)	MAXIMUM WALL STUD SPACING (inches)	PANEL NAIL SPACING		MAXIMUM NOMINAL DESIGN WIND SPEED, V_{asd}[d] (MPH)		
							Wind exposure category		
Size	Penetration (inches)				Edges (inches o.c.)	Field (inches o.c.)	B	C	D
6d common (2.0" × 0.113")	1.5	24/0	$^{3}/_{8}$	16	6	12	110	90	85
		24/16	$^{7}/_{16}$	16	6	12	110	100	90
						6	150	125	110
8d common (2.5" × 0.131")	1.75	24/16	$^{7}/_{16}$	16	6	12	130	110	105
						6	150	125	110
				24	6	12	110	90	85
						6	110	90	85

For SI: 1 inch = 25.4 mm, 1 mile per hour = 0.447 m/s.

a. Panel strength axis shall be parallel or perpendicular to supports. Three-ply plywood sheathing with studs spaced more than 16 inches on center shall be applied with panel strength axis perpendicular to supports.

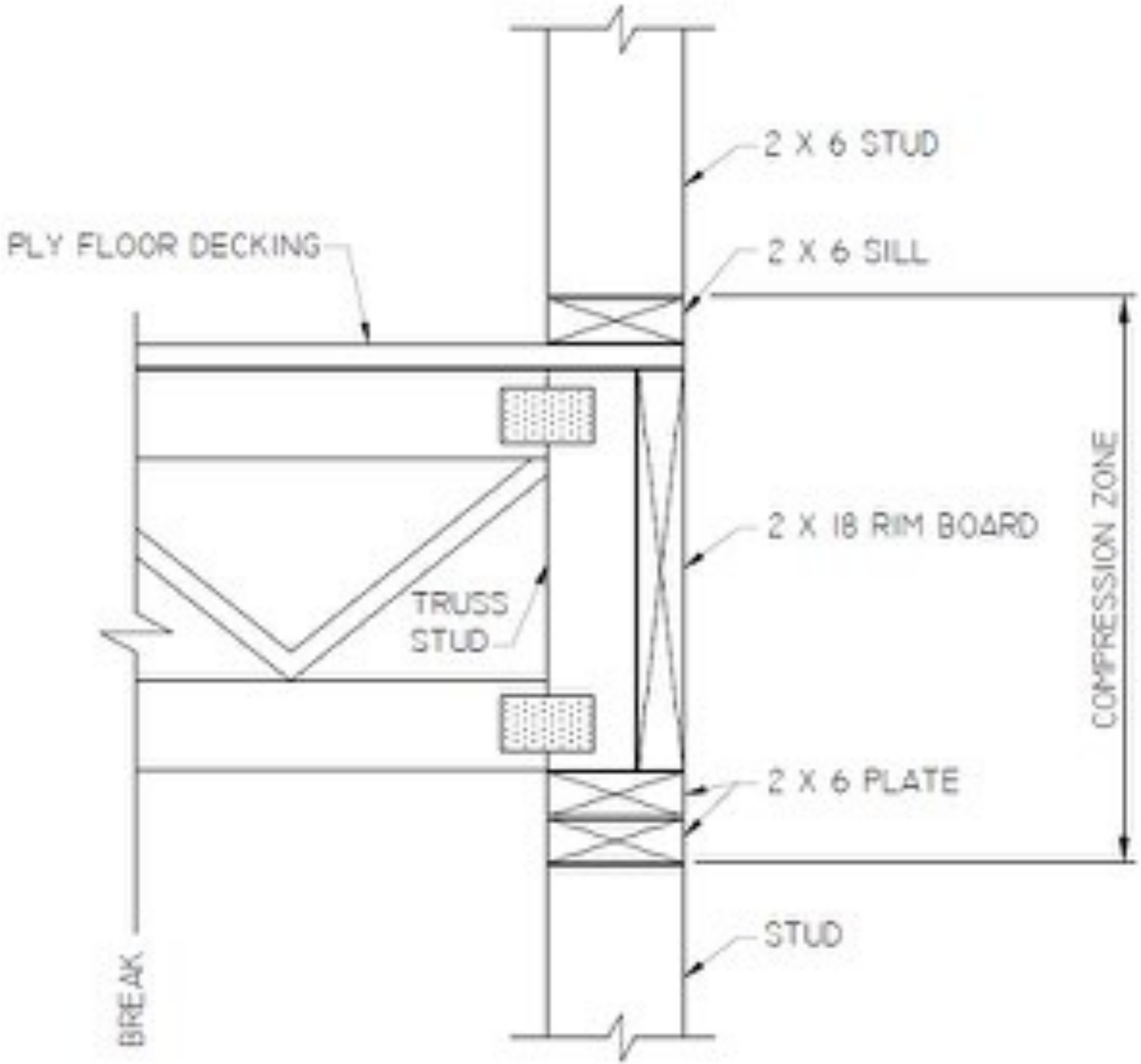
b. The table is based on wind pressures acting toward and away from building surfaces in accordance with Section 30.7 of ASCE 7. Lateral requirements shall be in accordance with Section 2305 or 2308.

c. Wood structural panels with span ratings of wall-16 or wall-24 shall be permitted as an alternative to panels with a 24/0 span rating. Plywood siding rated 16 on center or 24 on center shall be permitted as an alternative to panels with a 24/16 span rating. Wall-16 and plywood siding 16 on center shall be used with studs spaced a maximum of 16 inches on center.

d. V_{asd} shall be determined in accordance with Section 1609.3.1.

Design Conundrum:

- **Fastening of the exterior sheathing panel at the floor lines may become critical.**
  - **Must follow the code (or specific calcs)**
  - **Must resist wind loads**
- **However, if the sheathing bridges across the compression zone, it must also accom-modate the anticipated shrinkage and differential movement (shear diaphragms?).**
- **Detailing of this assembly would require special thought and (perhaps) compromise.**



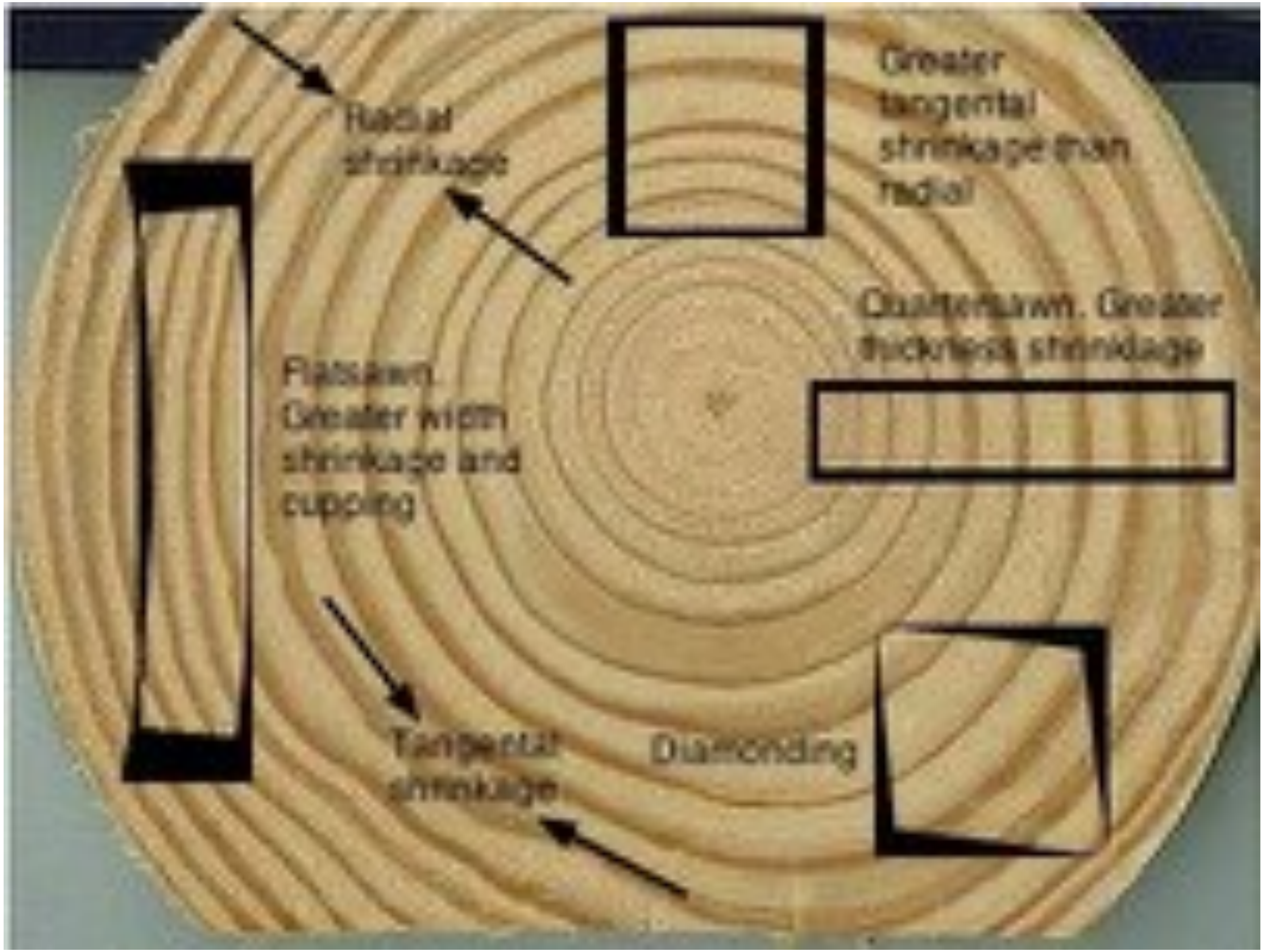
Typical code compliant fastening of exterior sheathing should not bridge across cross-sectional members subject to moisture shrinkage. Requires special detailing.

WOOD SCIENCE

- **Calculations can be performed to estimate these shrinkage dimensions – but examples of that exercise are beyond the scope of this presentation (see WWPA, 2002, and**
- **Wood-Works, 2017).**
- **Three variables having the most influence:**
  - **Initial moisture content**
  - **In-service MC, or equilibrium MC**
  - **Cumulative thickness of cross-grain wood elements**
- **Experience shows the shrinkage can commonly result in 0.25" to 0.30" (6.5 mm - 7.6 mm) per floor; cumulatively as much as 1.25" (32 mm).**

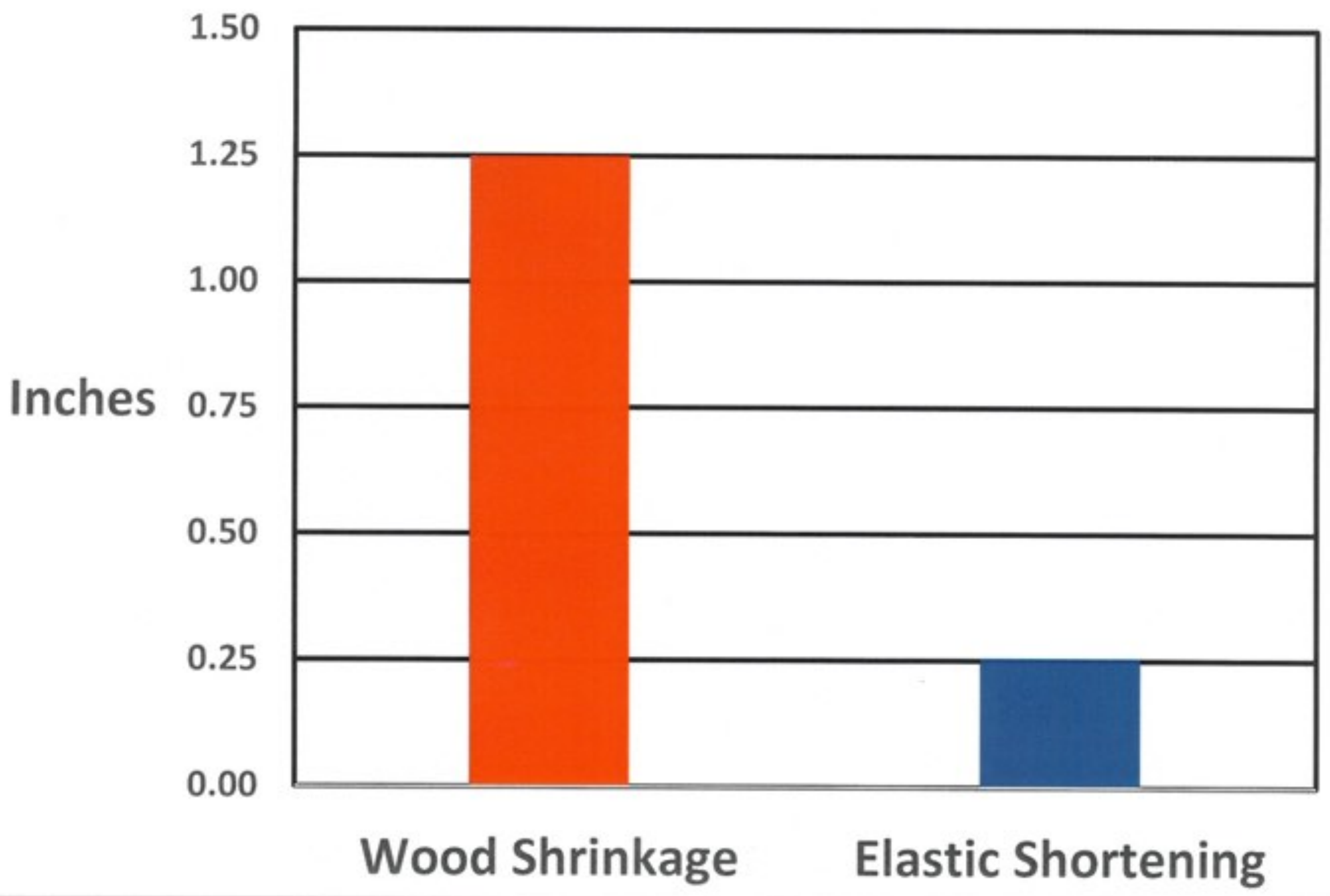
WOOD SCIENCE (con't.)

- Primarily members with cross-sectional dimensions (perpendicular to grain).
- Longitudinal shrinkage is negligible. Difficult to predict grain orientation.
- Shrinkage concentrated at plates, sills, floor joists, roof joists, and rim boards.
- As wood dries, the free water is released from the cell walls.
- Simplifying approximations typically utilize 1% of shrinkage for every 4% change in MC from 0-30 percent.



Radial shrinkage
Greater tangental shrinkage than radial
Quartersawn. Greater thickness shrinkage
Flatsawn. Greater width shrinkage and cupping
Tangental shrinkage
Diamonding

FIVE-STORY WOOD-FRAMED STRUCTURE



DIFFERENTIAL MOVEMENT:

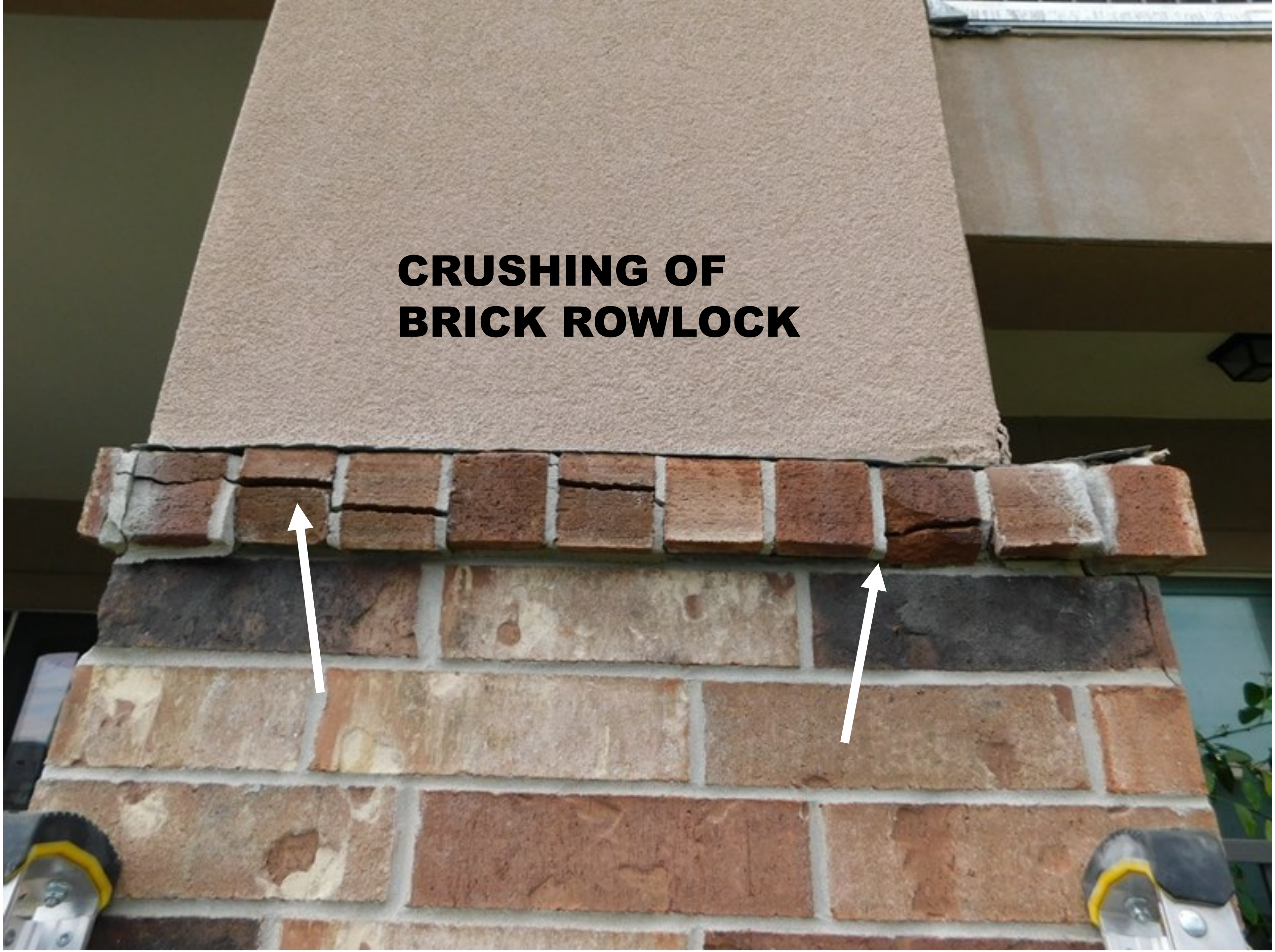
- **Designers must consider expansion and contraction (shrinkage) of components due to moisture, as well as thermal changes.**
- **Designers must consider overall movement and settlement of the structures and assemblies due to thermal, shortening, and shrinkage.**
- **Designers must consider “differences” between those materials subject to moisture shrinkage and those materials exhibiting little to no significant shrinkage over time.**
- **Differences regarding wood, masonry, plaster, cement board, and sheet metal.**

BRICK MASONRY VENEER

- **DIFFERENTIAL MOVEMENT:**
  - FRAMING-TO-CLADDING
  - CLADDING-TO-OPENINGS

- **OPENINGS:**
  - WINDOWS AND DOORS
  - BALCONIES

- **CLADDING TRANSITIONS:**

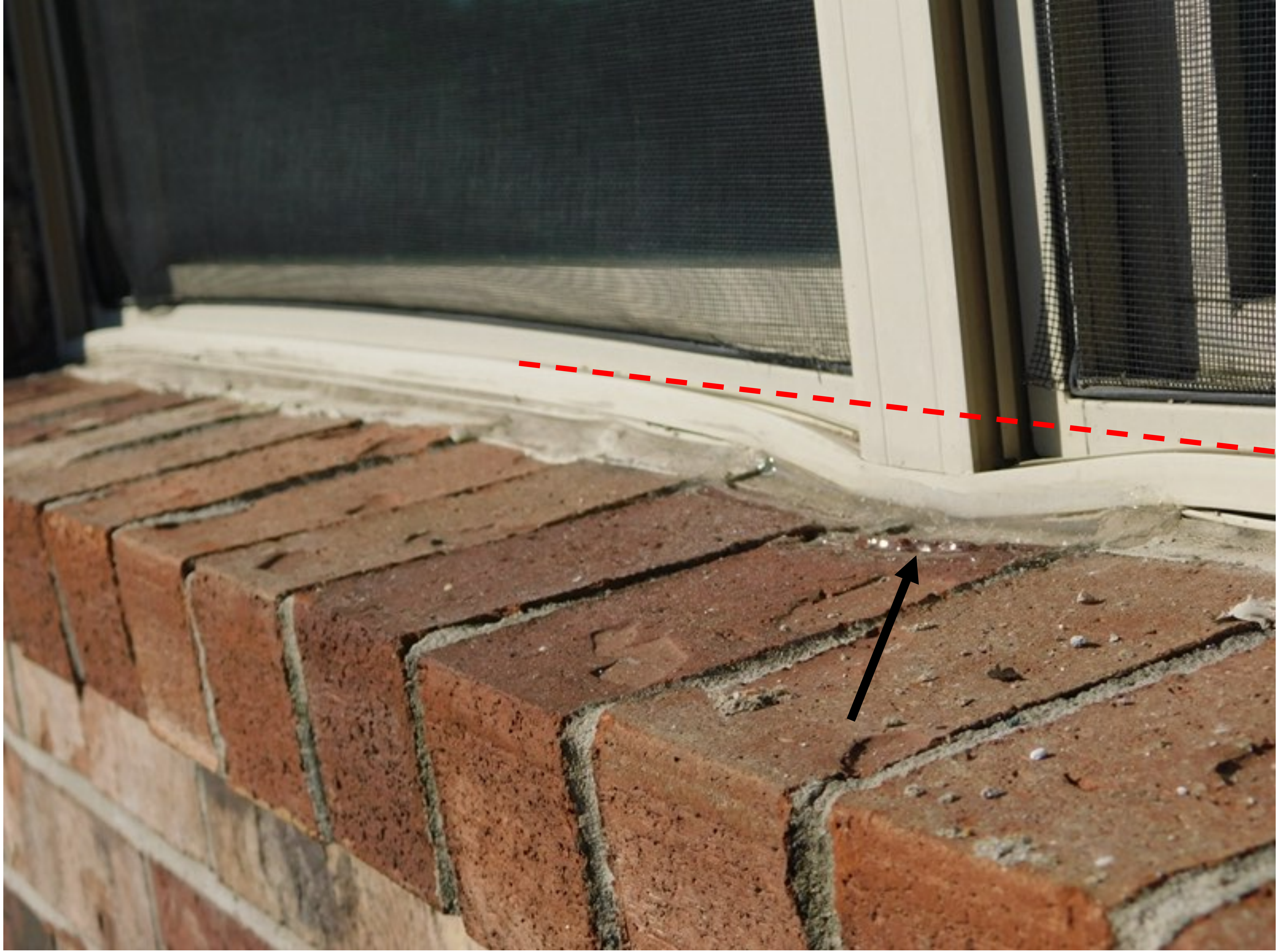

CRUSHING OF
BRICK ROWLOCK

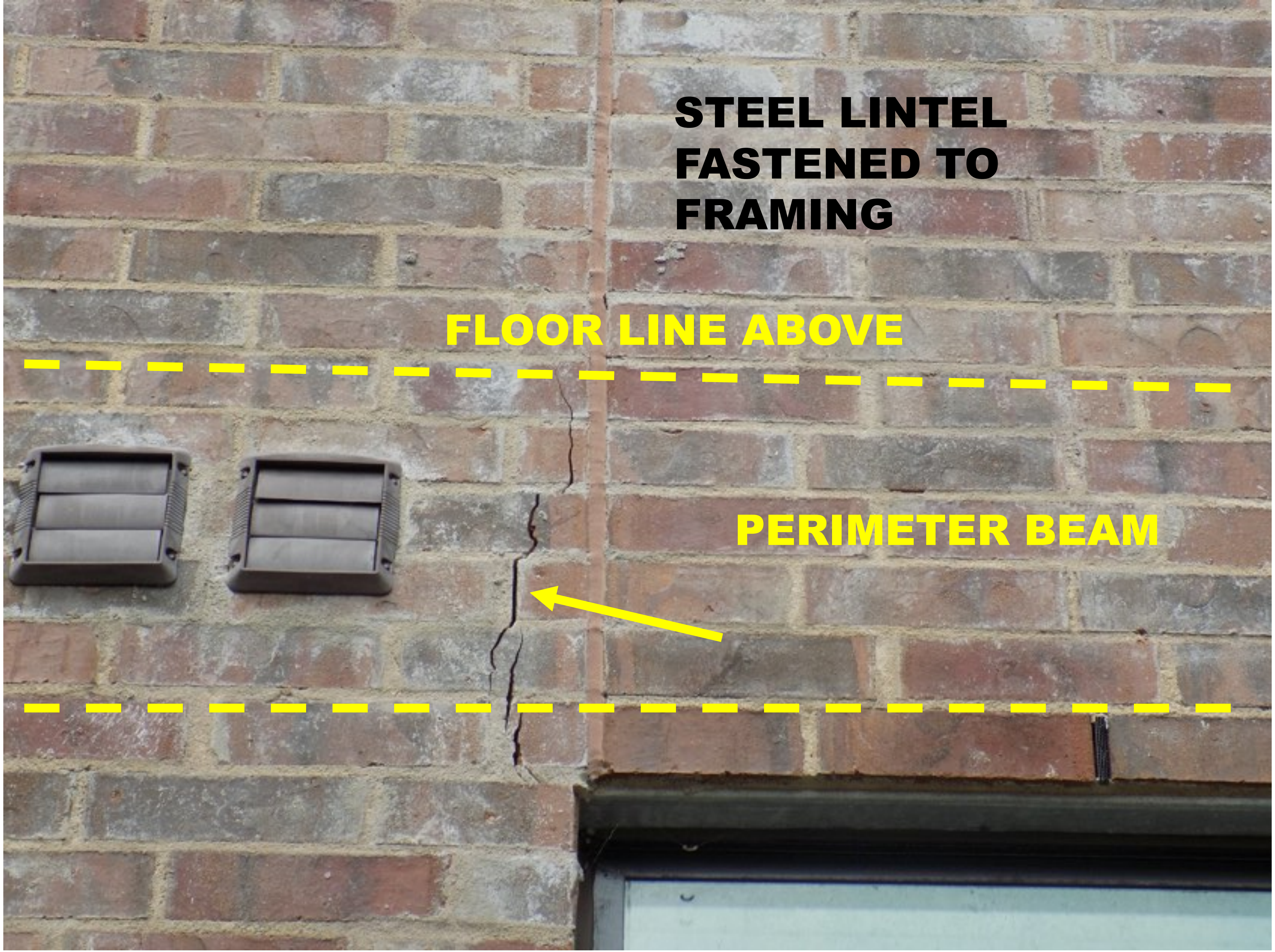

CRUSHING
OF PLASTER


FLASHING
DISPLACEMENT

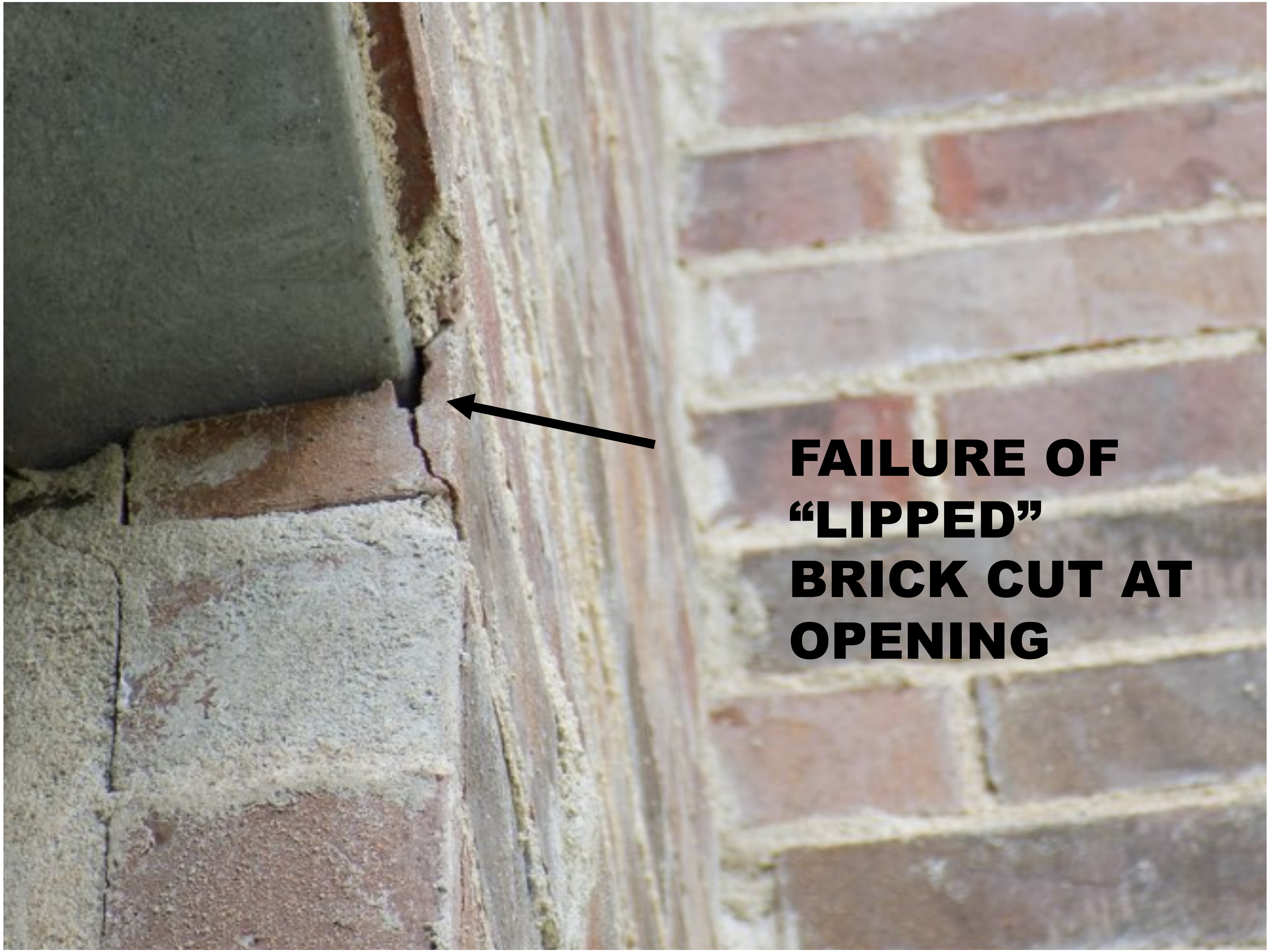

WATER
INTRUSION AT
SHEET METAL
LAP JOINT


DEFORMATION
OF WINDOW
FRAME

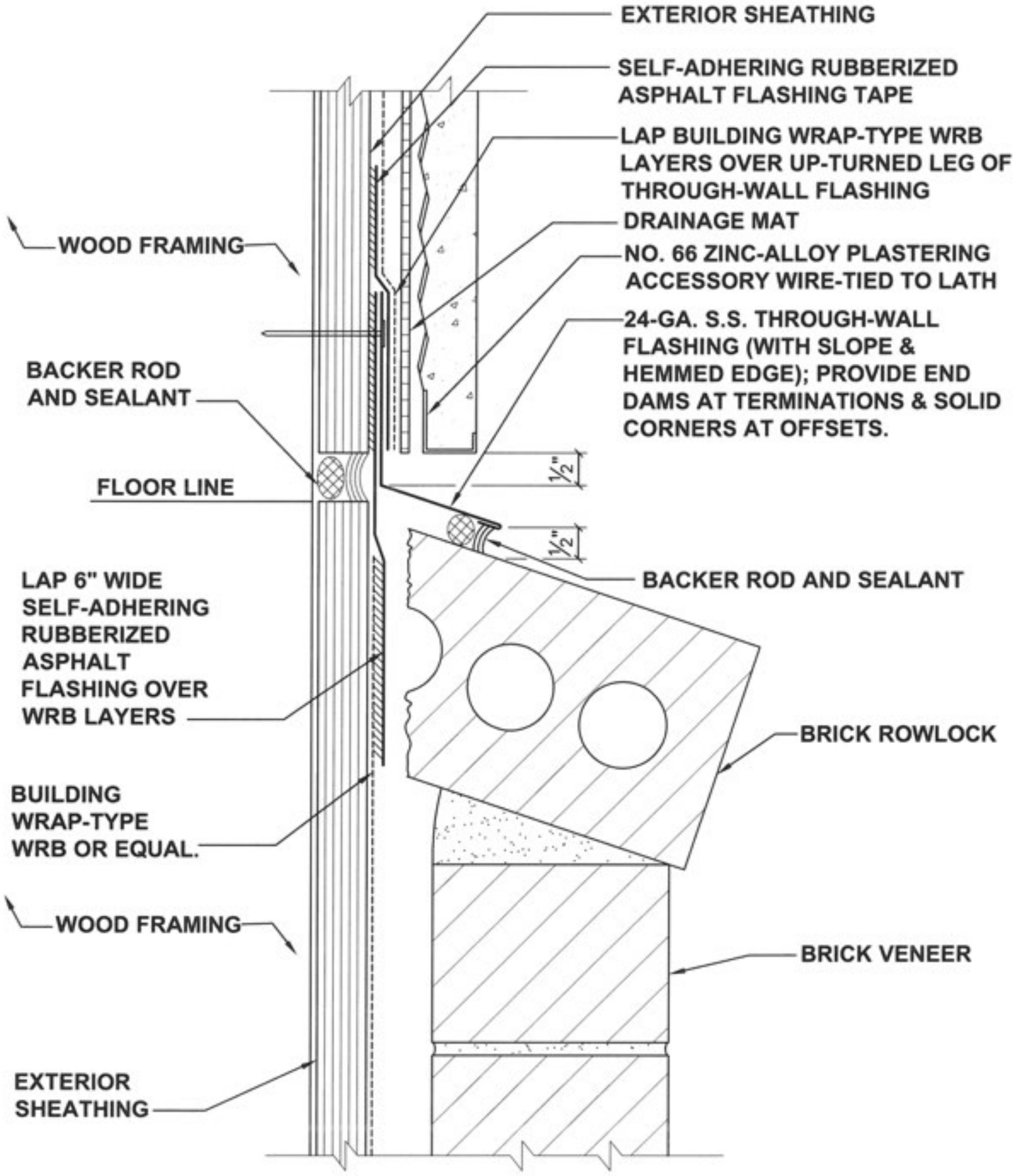



STEEL LINTEL
FASTENED TO
FRAMING
FLOOR LINE ABOVE
PERIMETER BEAM


COMPRESSION
FAILURE AT
OPENING LINTEL


FAILURE OF
“LIPPED”
BRICK CUT AT
OPENING


SEALANT FAILURE



Transition From Plaster-to-Masonry

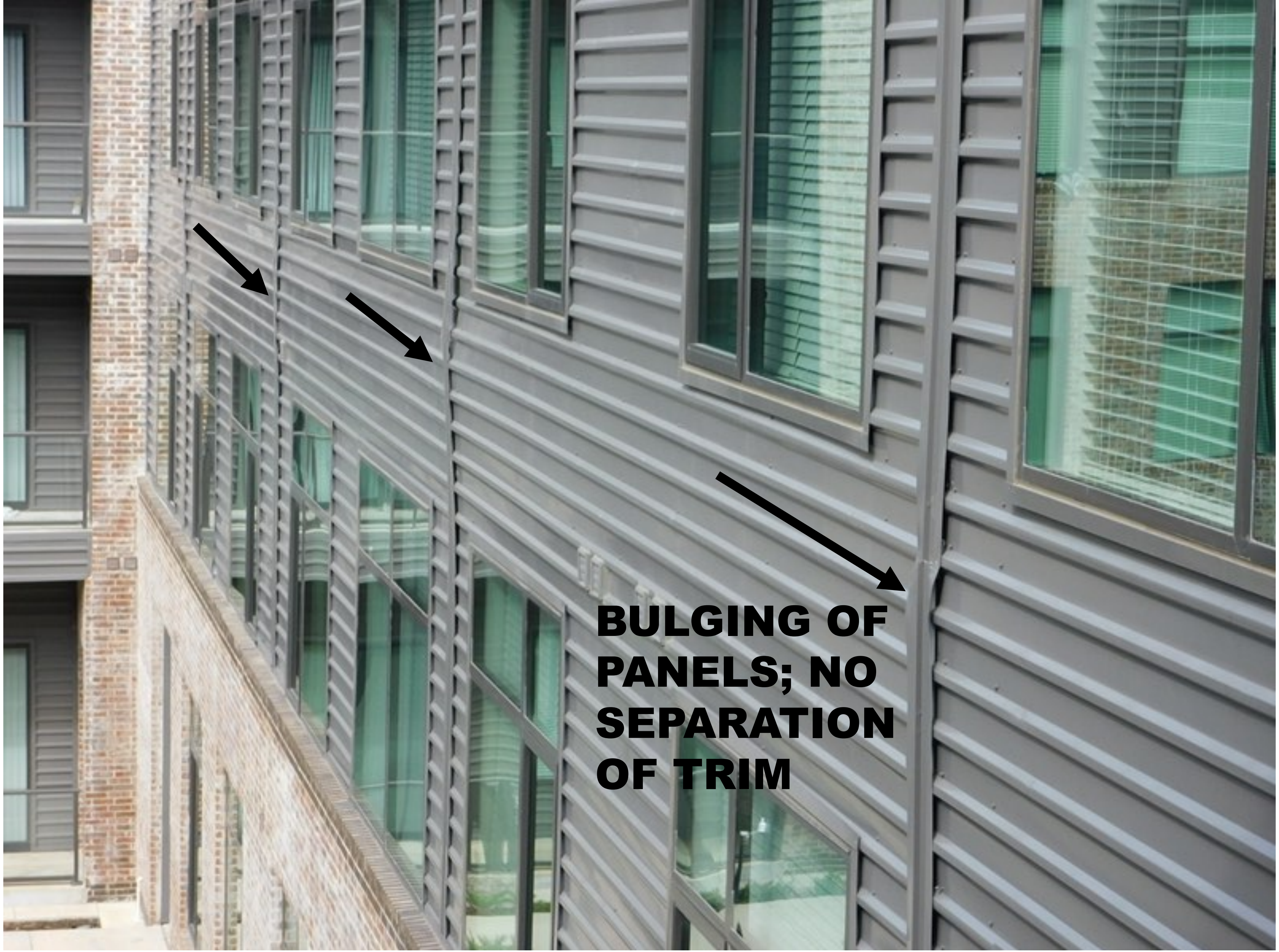
METAL PANEL SYSTEMS

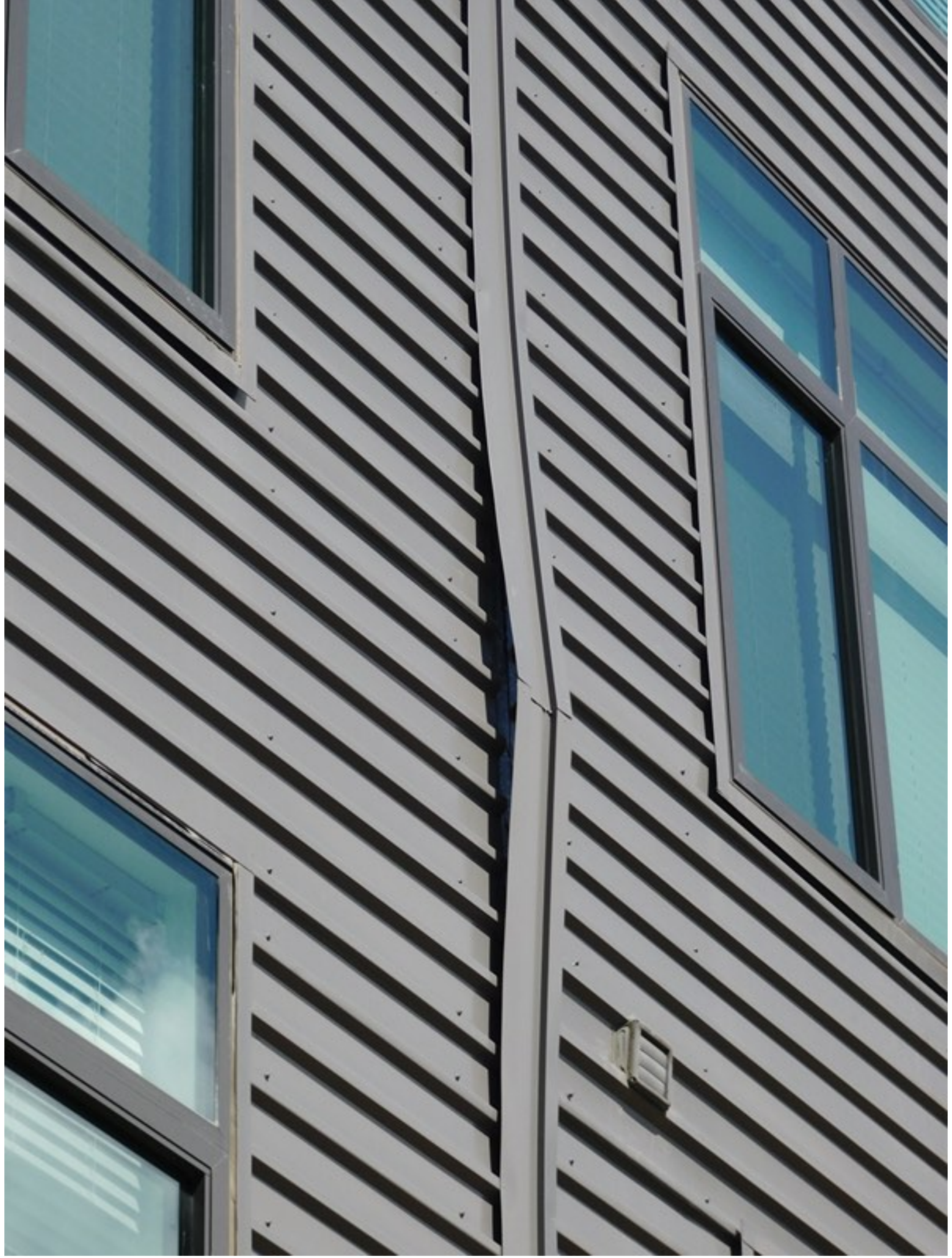
- **DIFFERENTIAL MOVEMENT:**
  - FRAMING-TO-CLADDING
  - CLADDING-TO-OPENINGS

- **MANIFESTATIONS:**
  - BULGING OF EXTERIOR SHEATHING
  - SEPARATION OF TRIM
  - OIL CANNING OF SHEET METAL
  - COMPRESSION OF SHEET METAL


BULGING
SEPARATION
TRANSITION


SEPARATION
OF TRIM

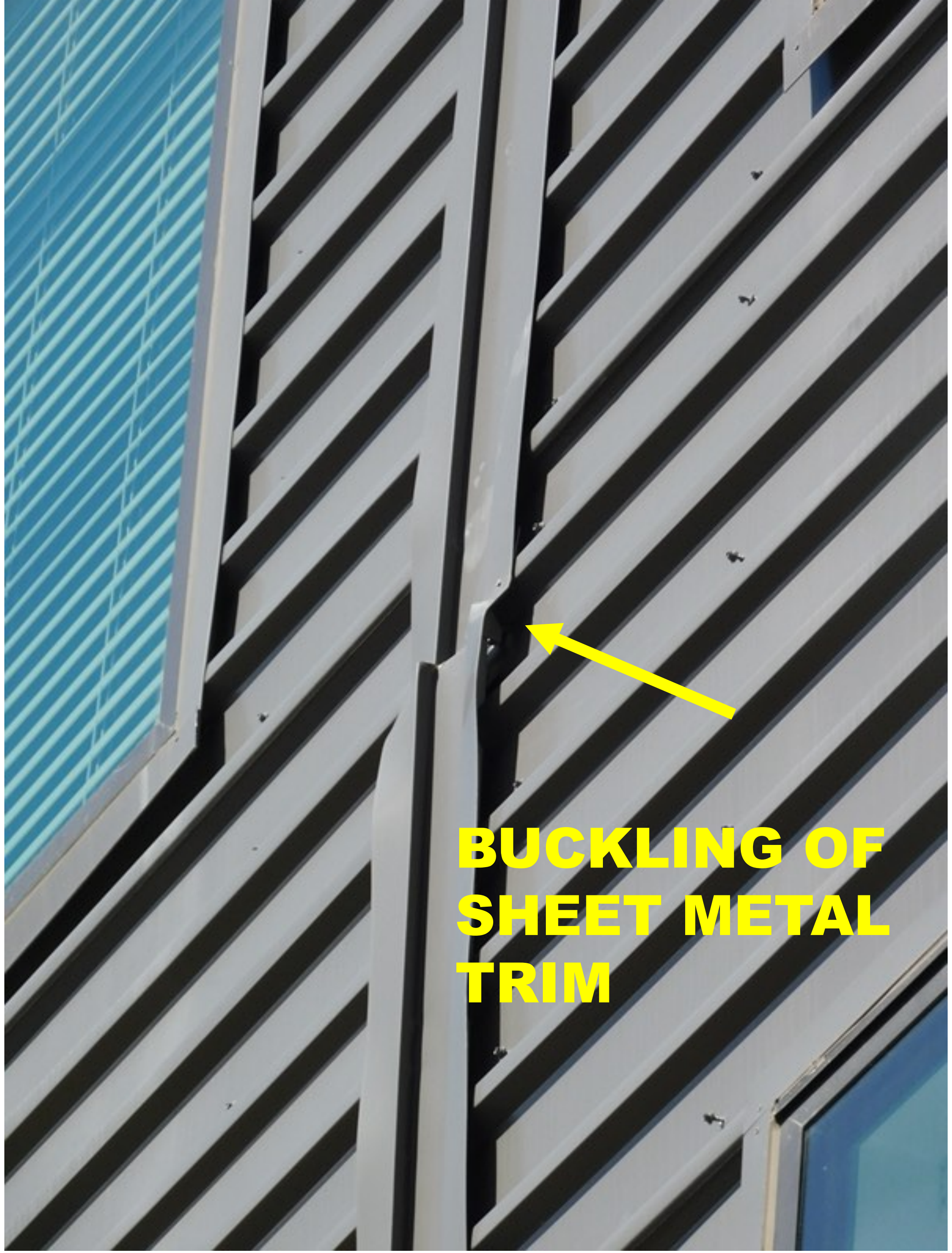

BULGING OF
PANELS; NO
SEPARATION
OF TRIM

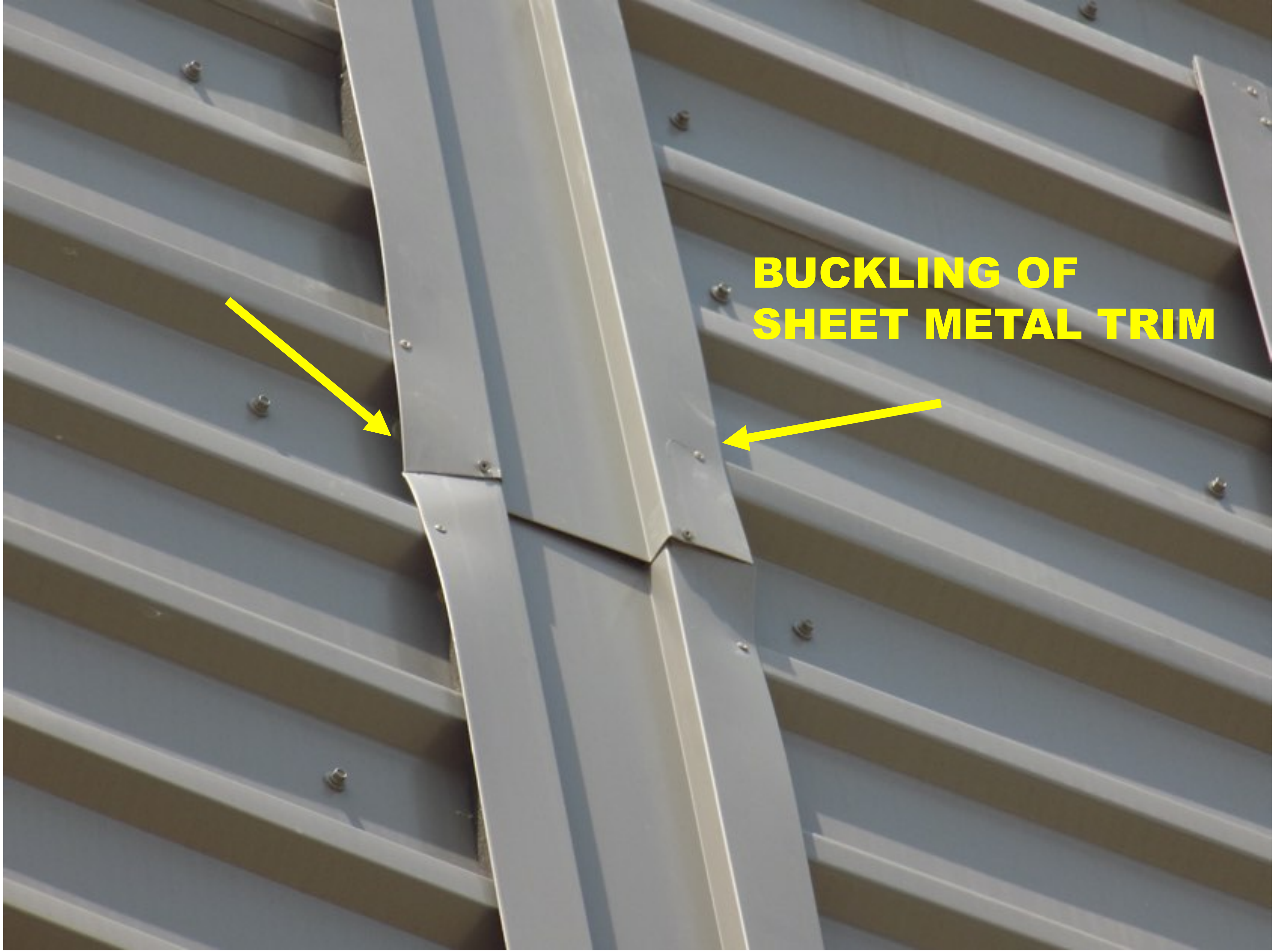



OIL-CANNING
OF SHEET
METAL

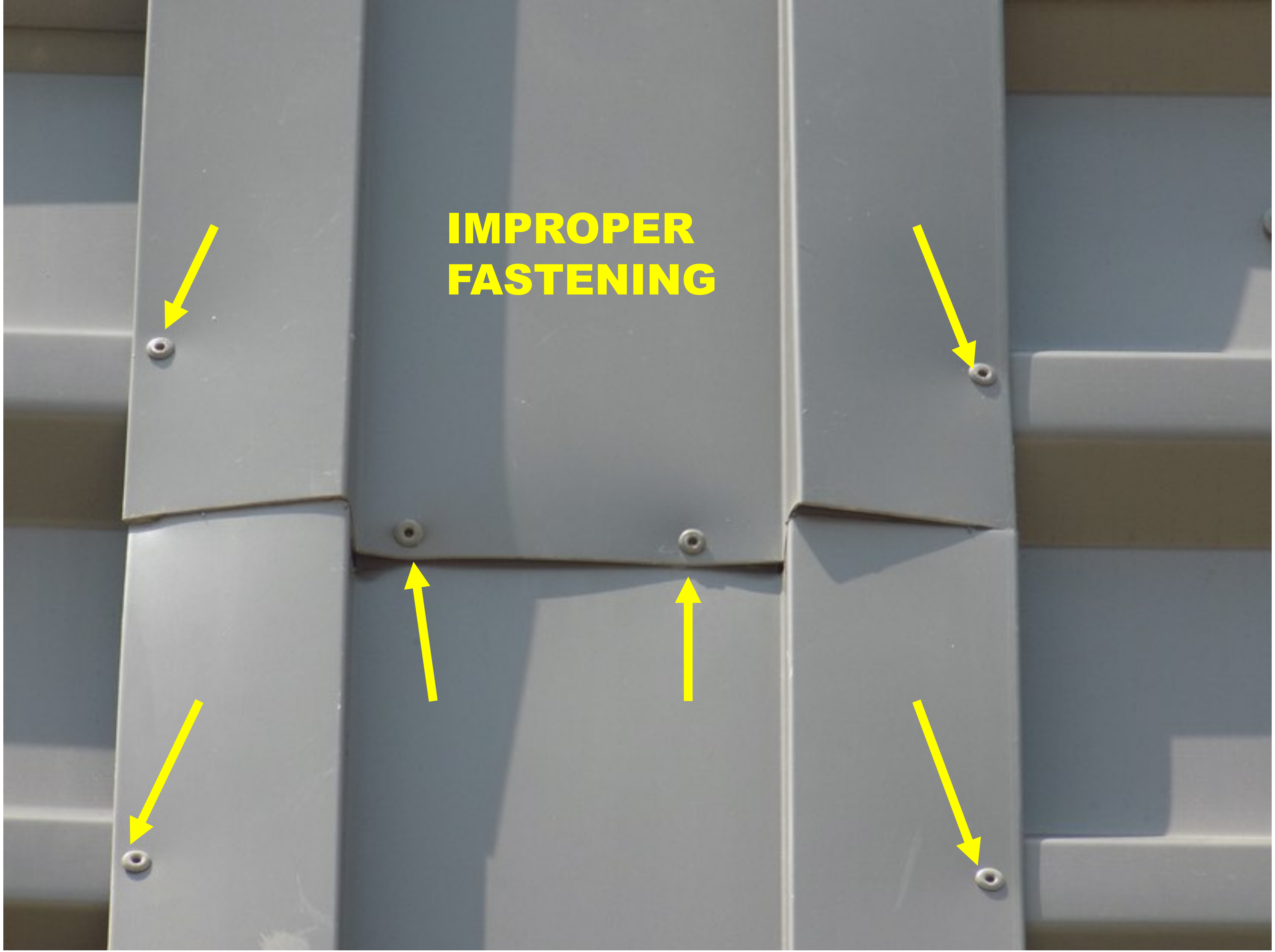

JULY 11, 2018
19 MONTHS AFTER
COMPLETION

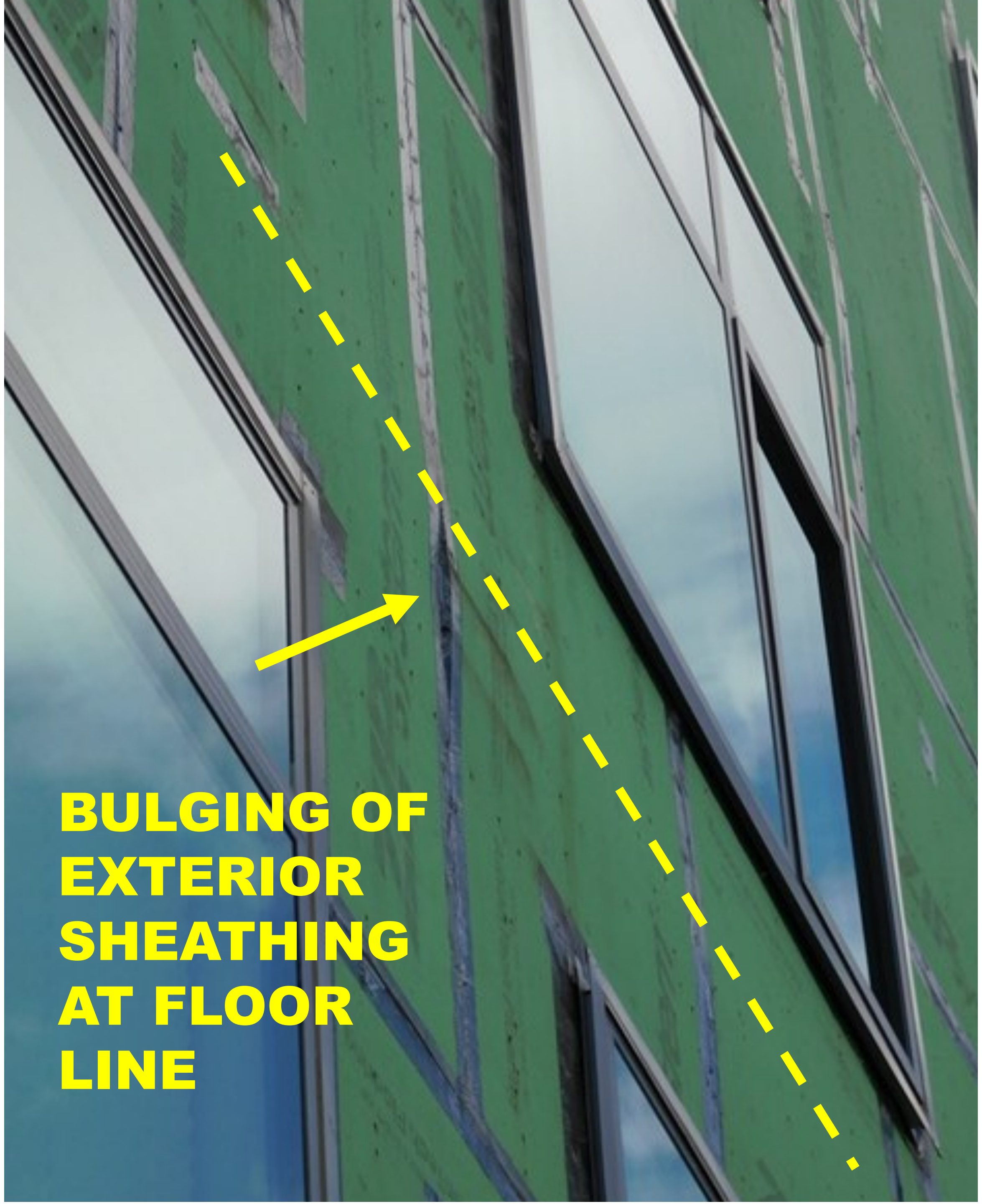

SEPTEMBER 23, 2019
33 MONTHS AFTER
COMPLETION

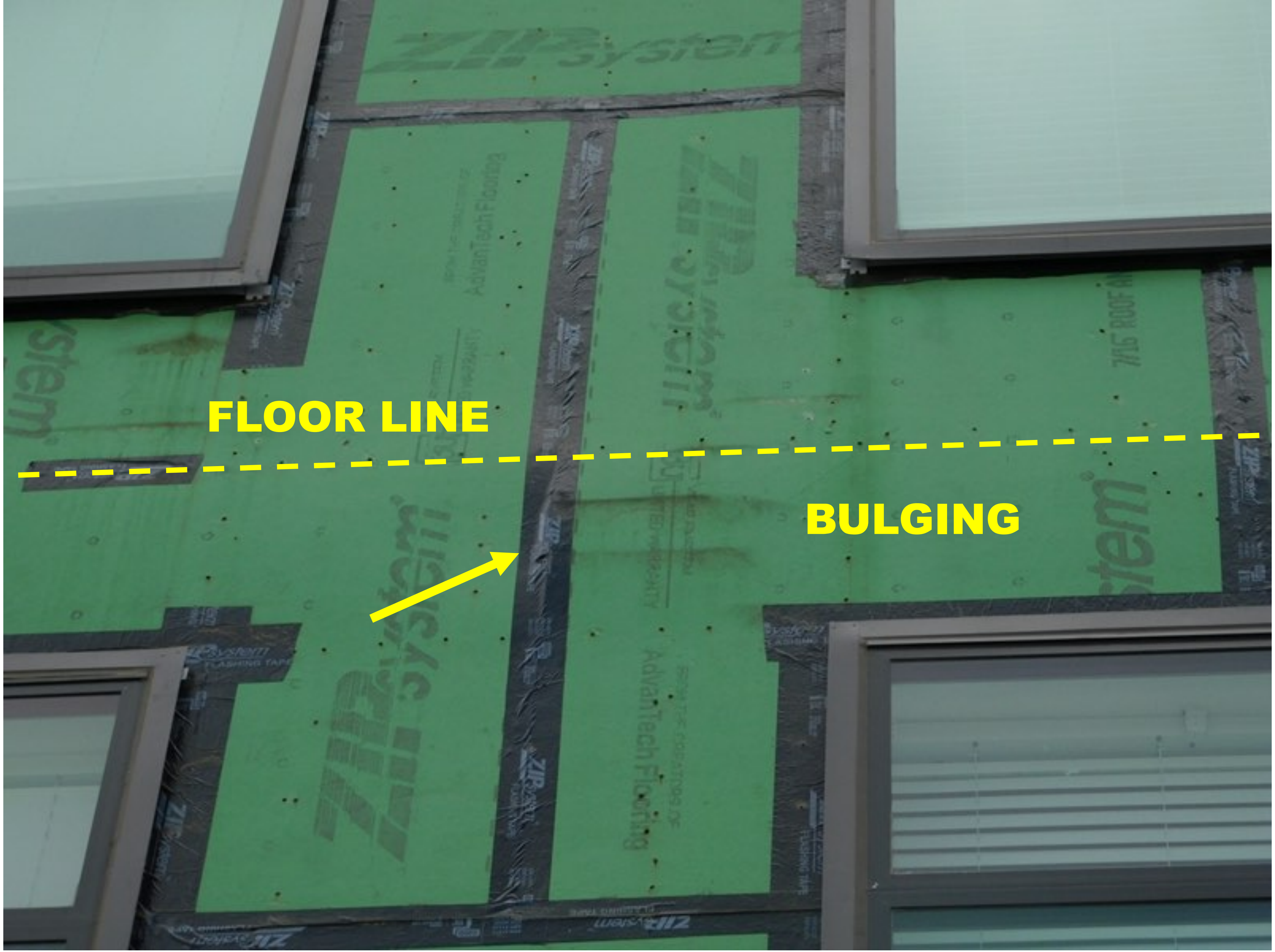

BUCKLING OF
SHEET METAL
TRIM

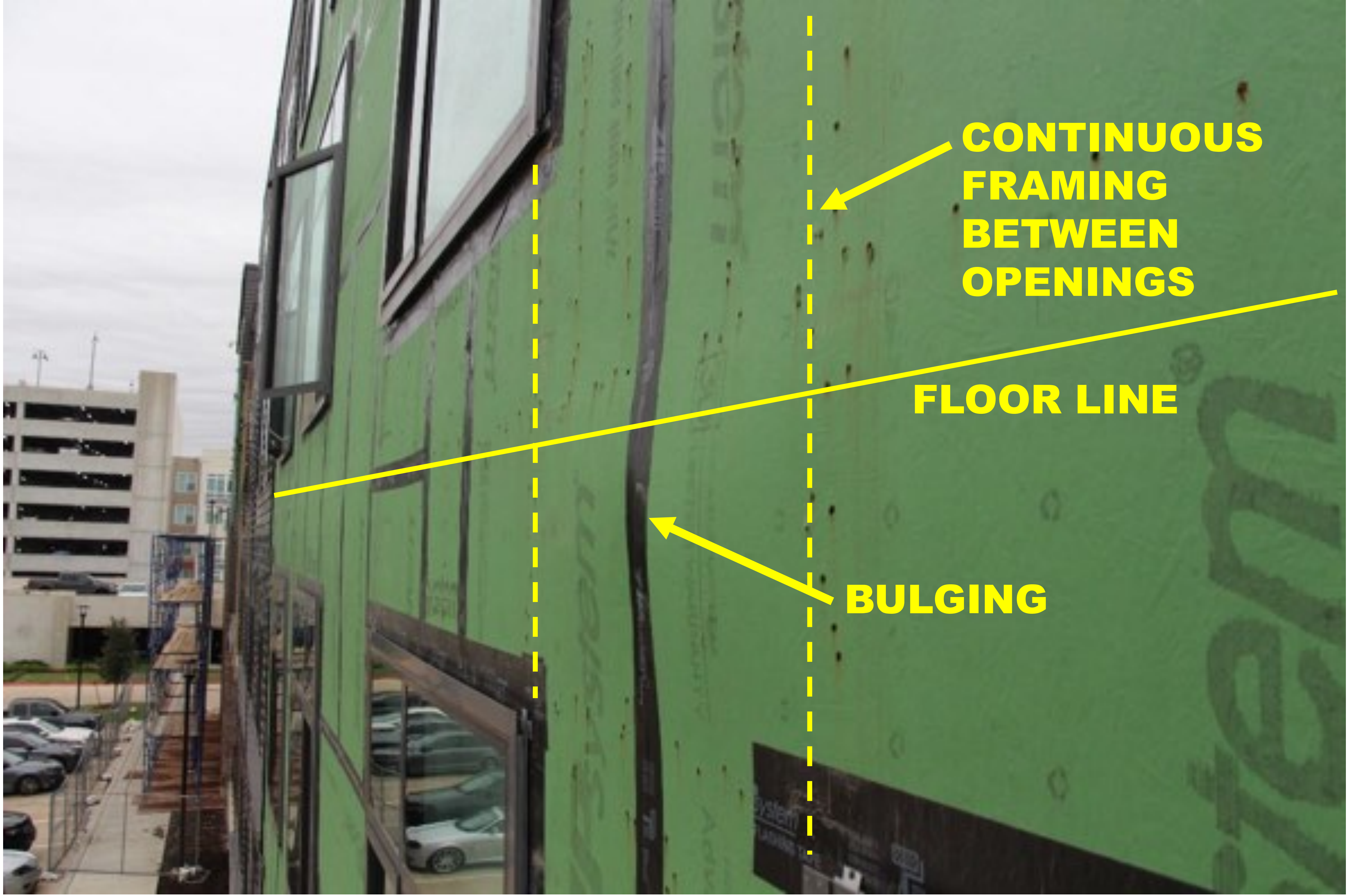

BUCKLING OF
SHEET METAL TRIM

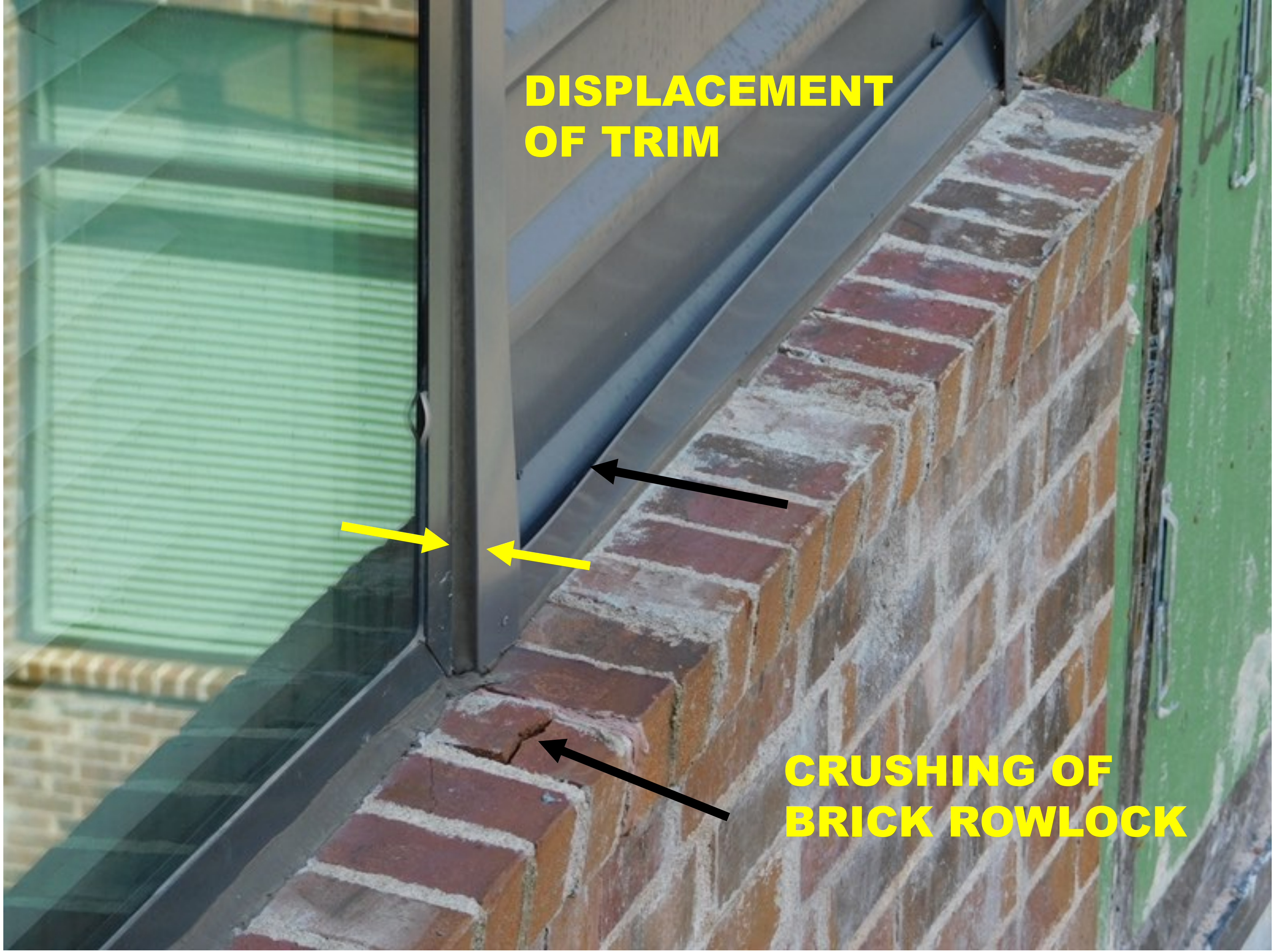

BUCKLING OF SHEET
METAL TRIM

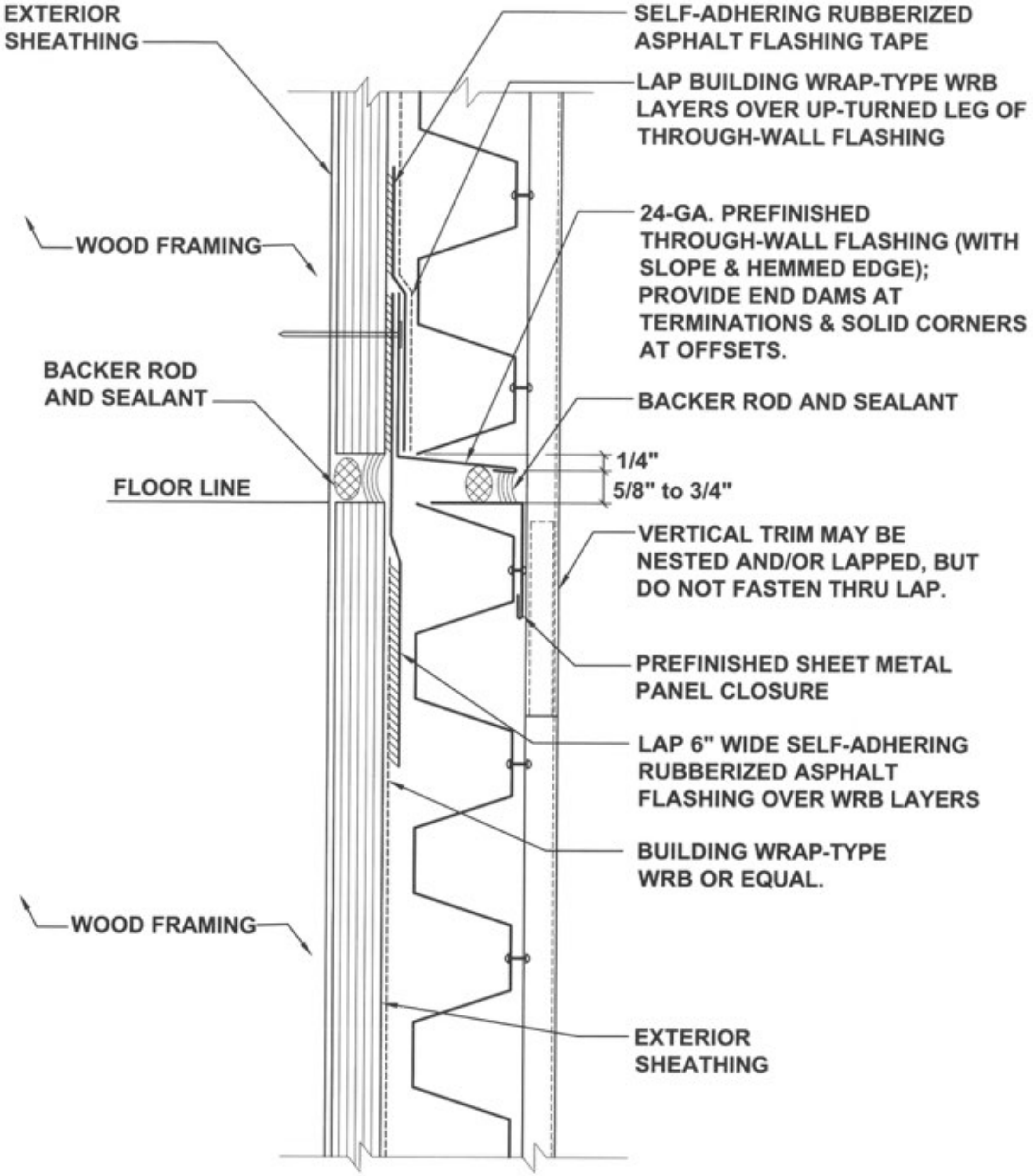

IMPROPER
FASTENING


BULGING OF
EXTERIOR
SHEATHING
AT FLOOR
LINE


FLOOR LINE
BULGING


CONTINUOUS
FRAMING
BETWEEN
OPENINGS
FLOOR LINE
BULGING


DISPLACEMENT OF TRIM
CRUSHING OF BRICK ROWLOCK

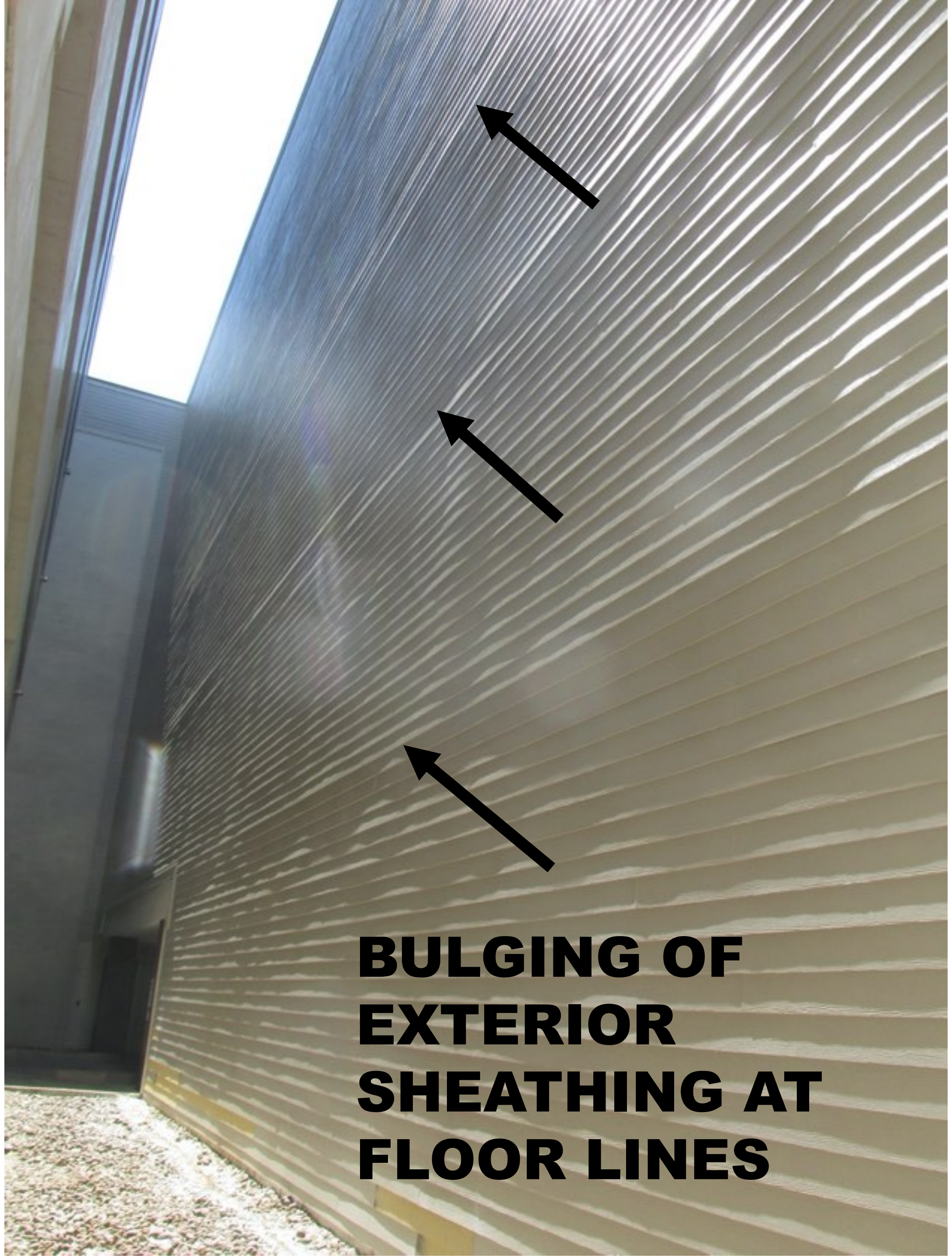


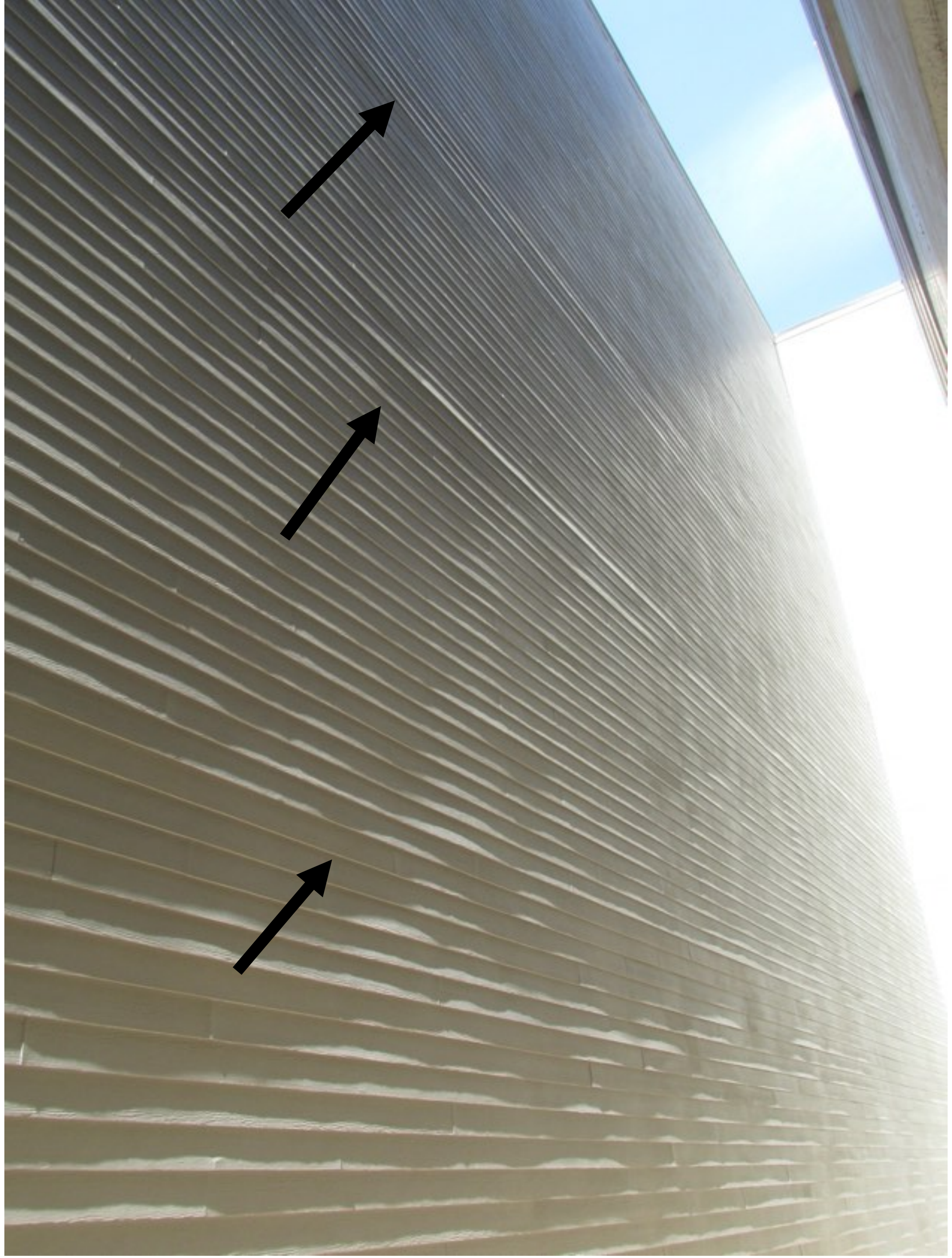
Metal Panels and Trim at Floor Line

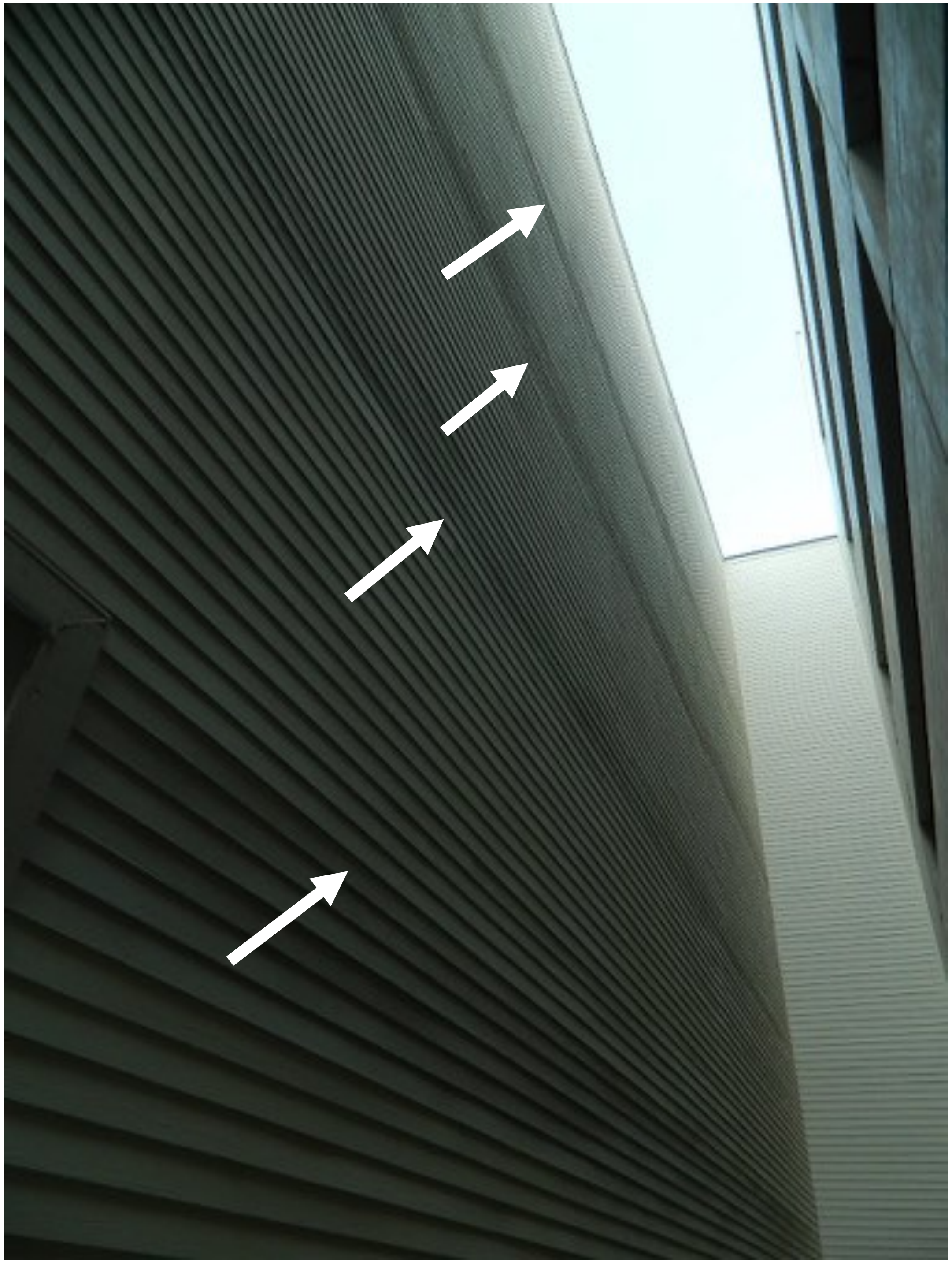
LAP SIDING

- DIFFERENTIAL MOVEMENT:
  - FRAMING-TO-CLADDING
  - CLADDING-TO-OPENINGS

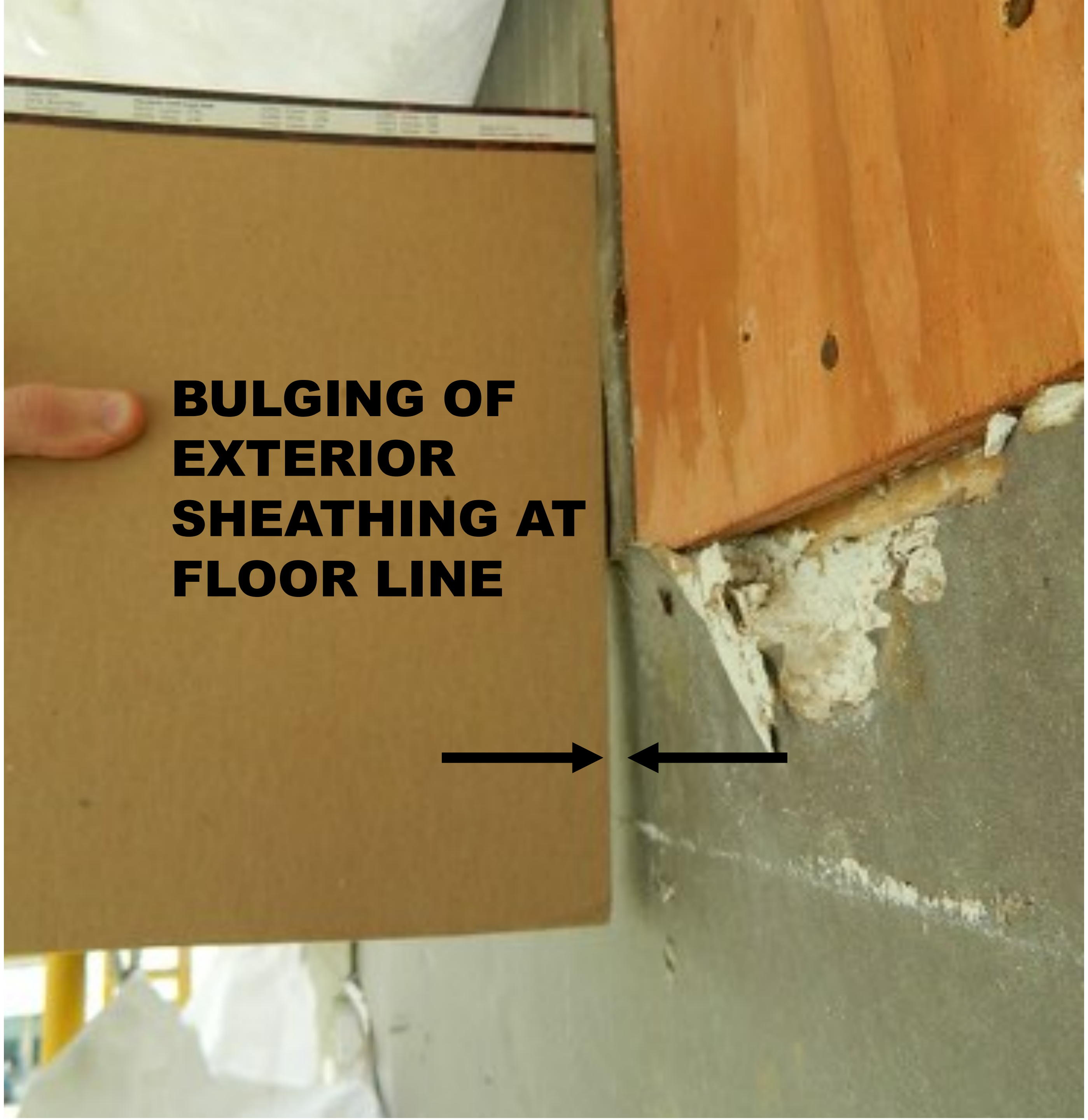
- MANIFESTATIONS:
  - BULGING OF EXTERIOR SHEATHING
  - DISPLACEMENT OF SHEET METAL
  - NAIL WITHDRAWAL DUE TO BULGING

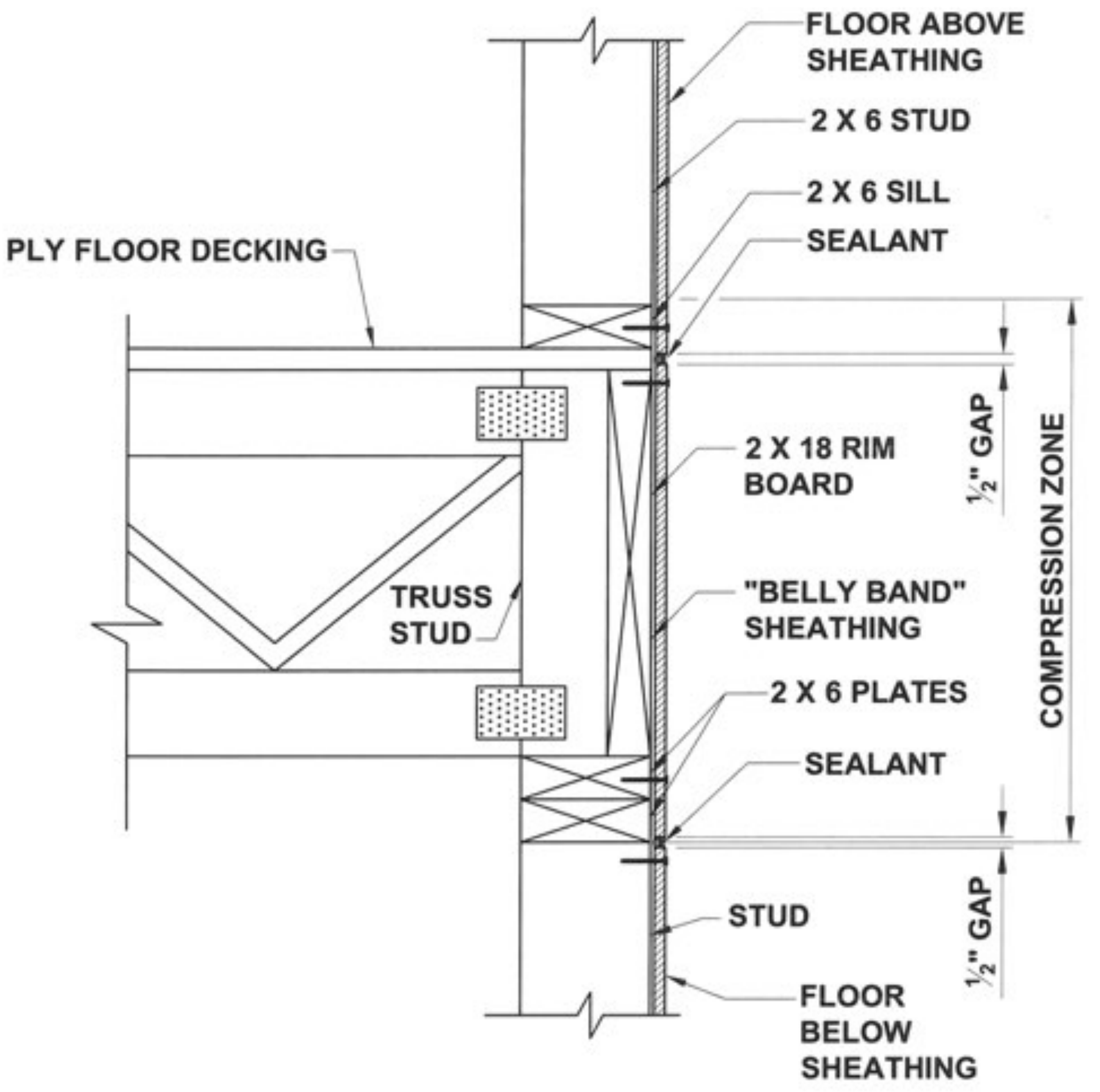

BULGING OF
EXTERIOR
SHEATHING AT
FLOOR LINES






COLLECTED
WATER RUNS OFF
END OF FLASHING
BEHIND SIDING
DuPont Flashing Systems


BULGING OF
EXTERIOR
SHEATHING AT
FLOOR LINE

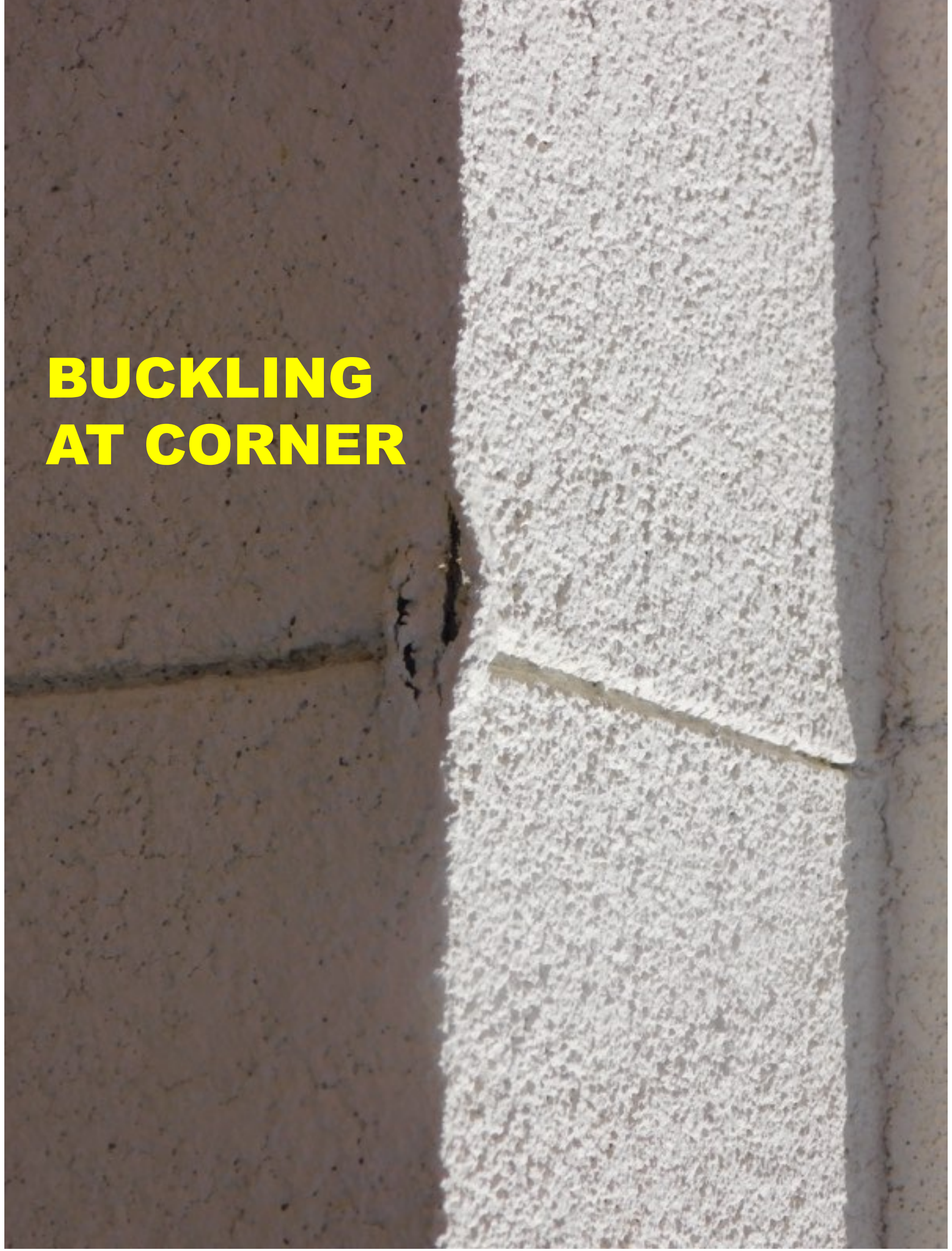


Typical Sheathing Fastening at Floor Line

PLASTER (STUCCO) AND EIFS

- **DIFFERENTIAL MOVEMENT:**
  - FRAMING-TO-CLADDING
  - CLADDING-TO-OPENINGS

- **MANIFESTATIONS:**
  - BULGING OF EXTERIOR SHEATHING
  - COMPRESSION OF CONTROL JOINTS
  - BUCKLING OF PLASTER ACCESSORIES
  - CRACKING OF PLASTER & EIFS

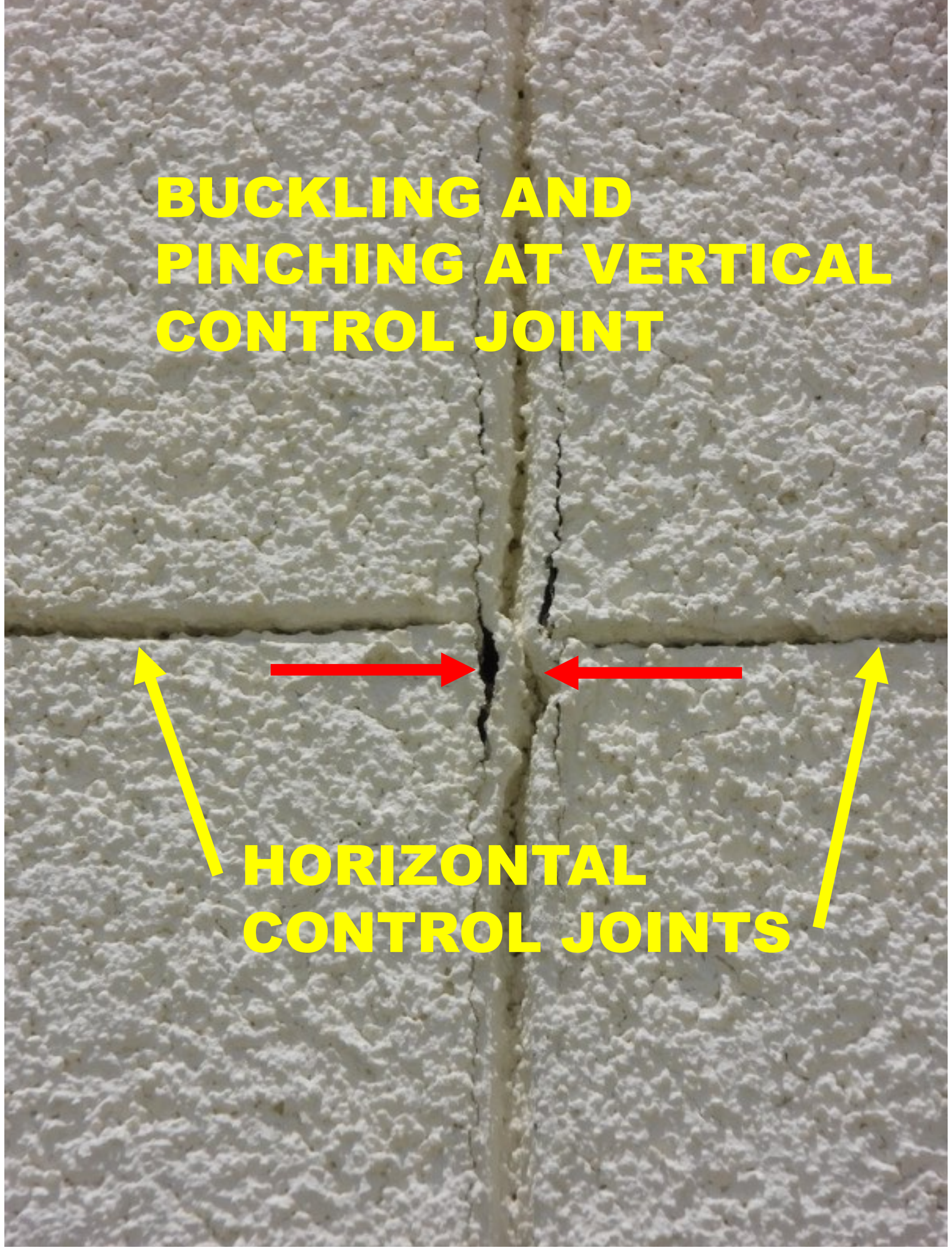

BUCKLING
AT CORNER


BUCKLING
AT CORNER

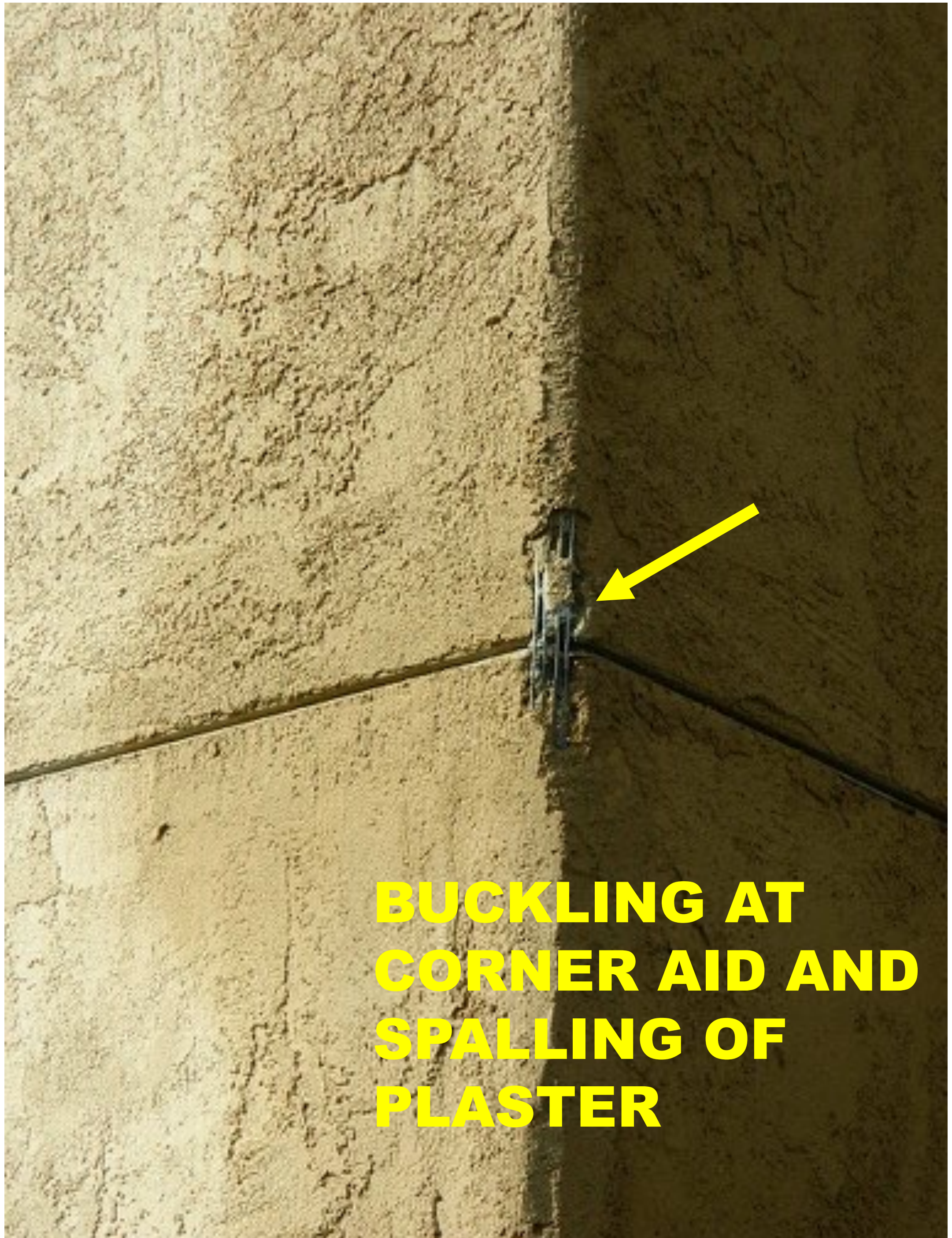

BUCKLING AT
VERTICAL
CONTROL JOINT
(MINOR)


BUCKLING AT
VERTICAL
CONTROL JOINT
(MODERATE)

BUCKLING AT VERTICAL CONTROL JOINT (SEVERE)
SEPARATION ALONG C.J.

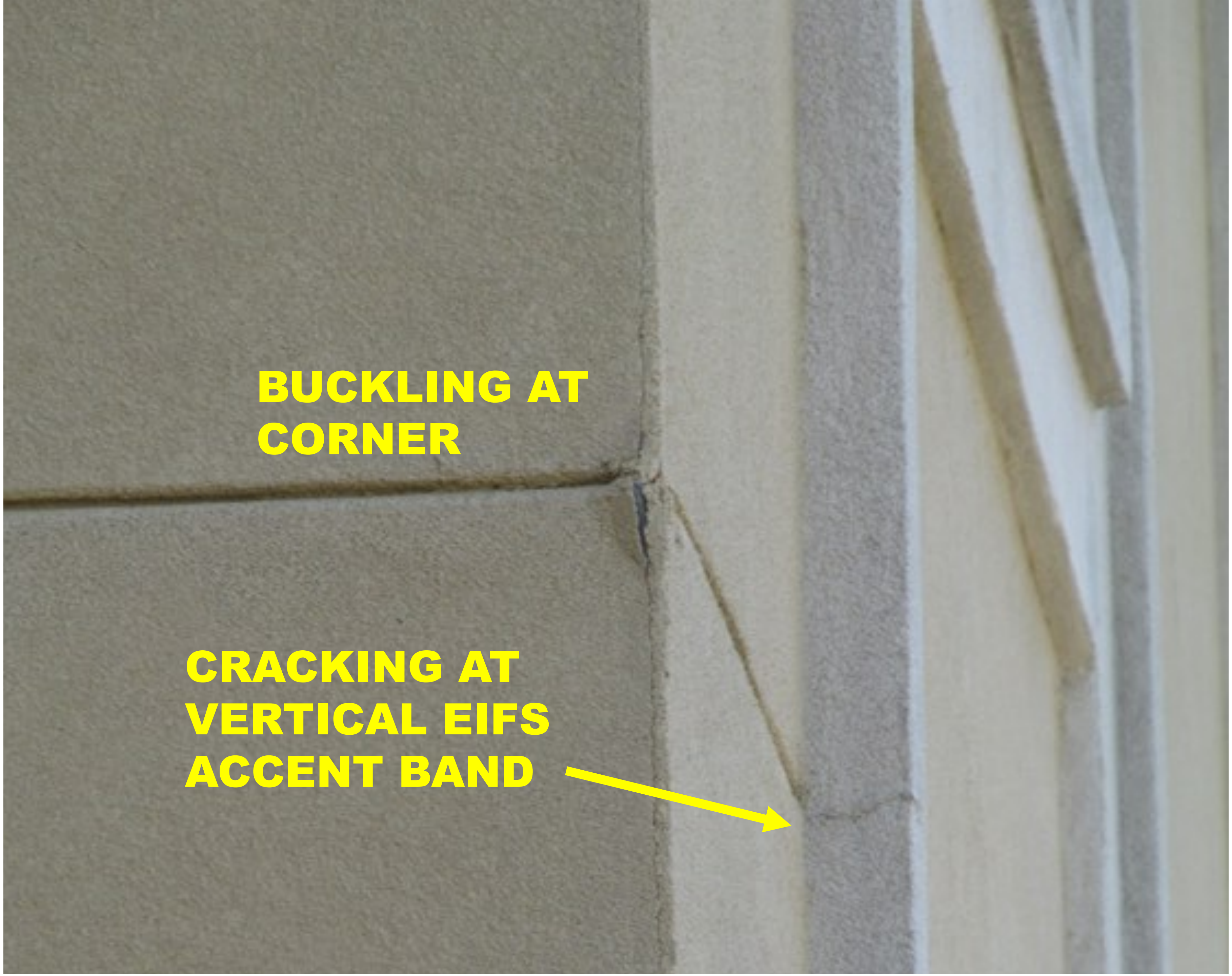

BUCKLING AND
PINCHING AT VERTICAL
CONTROL JOINT
HORIZONTAL
CONTROL JOINTS


BUCKLING AT
CORNER AID AND
SPALLING OF
PLASTER

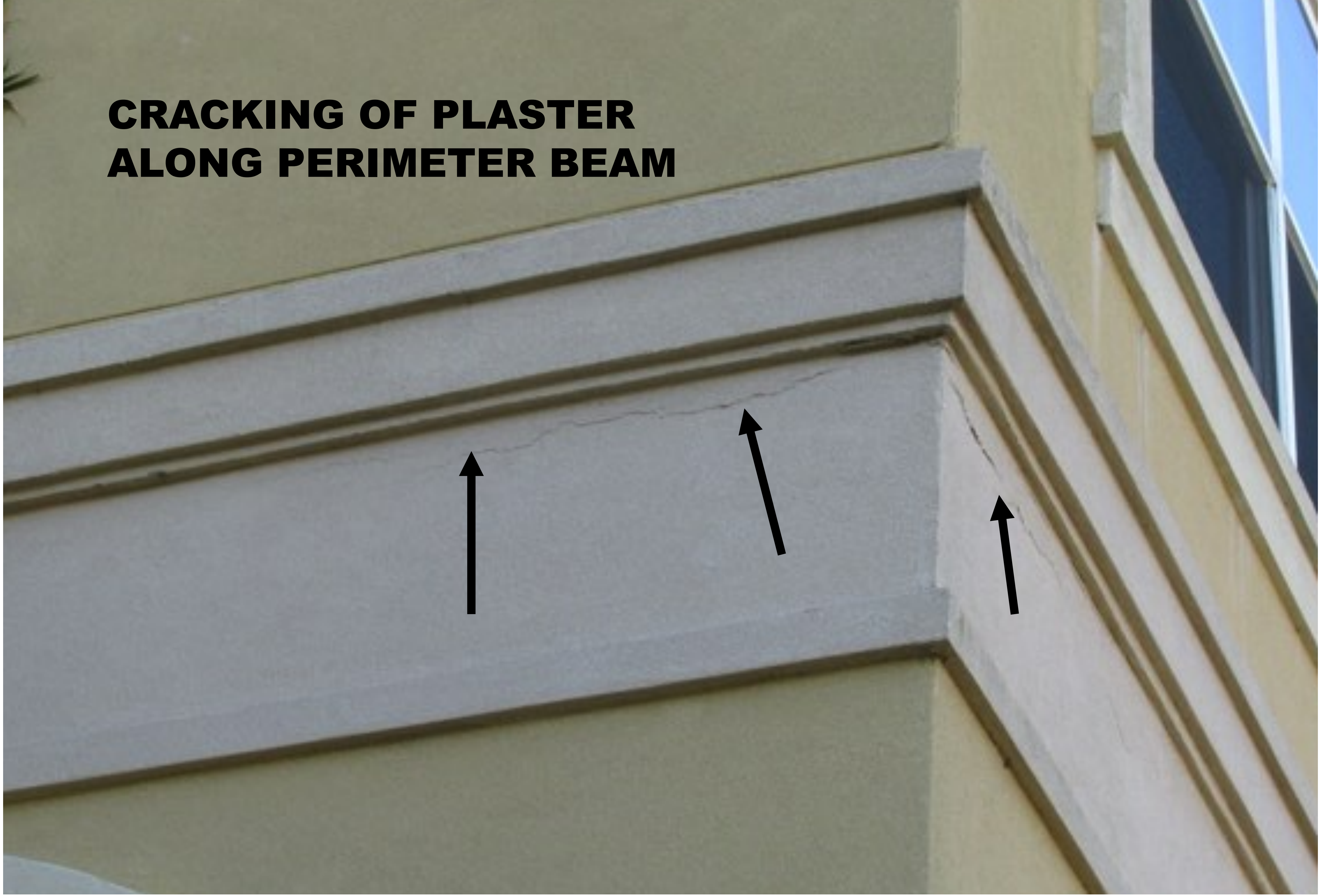

BUCKLING AT
CORNER AID AND
SPALLING OF
PLASTER


BUCKLING AT
VERTICAL
CONTROL JOINT

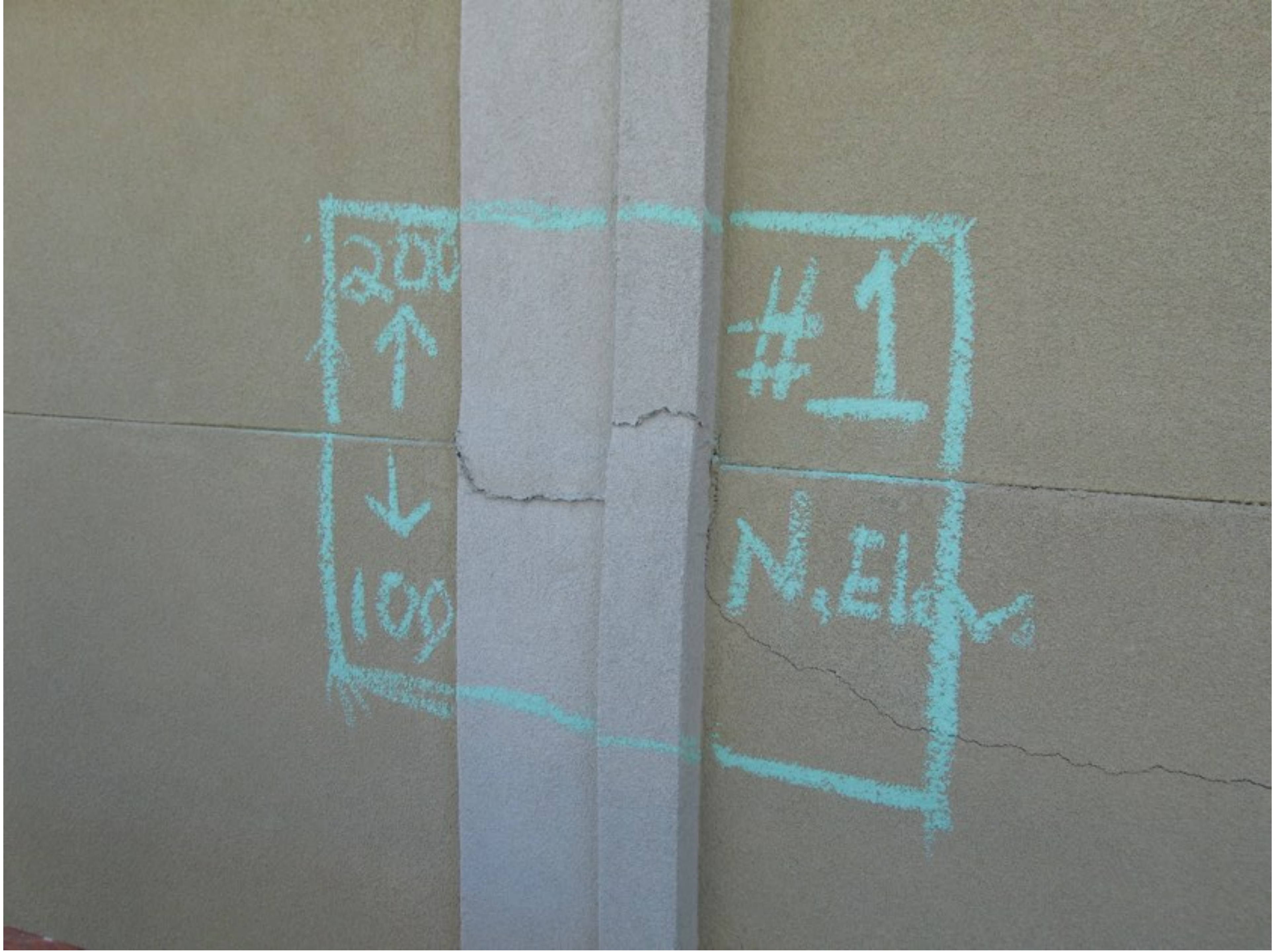

BUCKLING AT
VERTICAL
CONTROL JOINT
(SEVERE)


BUCKLING AT
CORNER
CRACKING AT
VERTICAL EIFS
ACCENT BAND

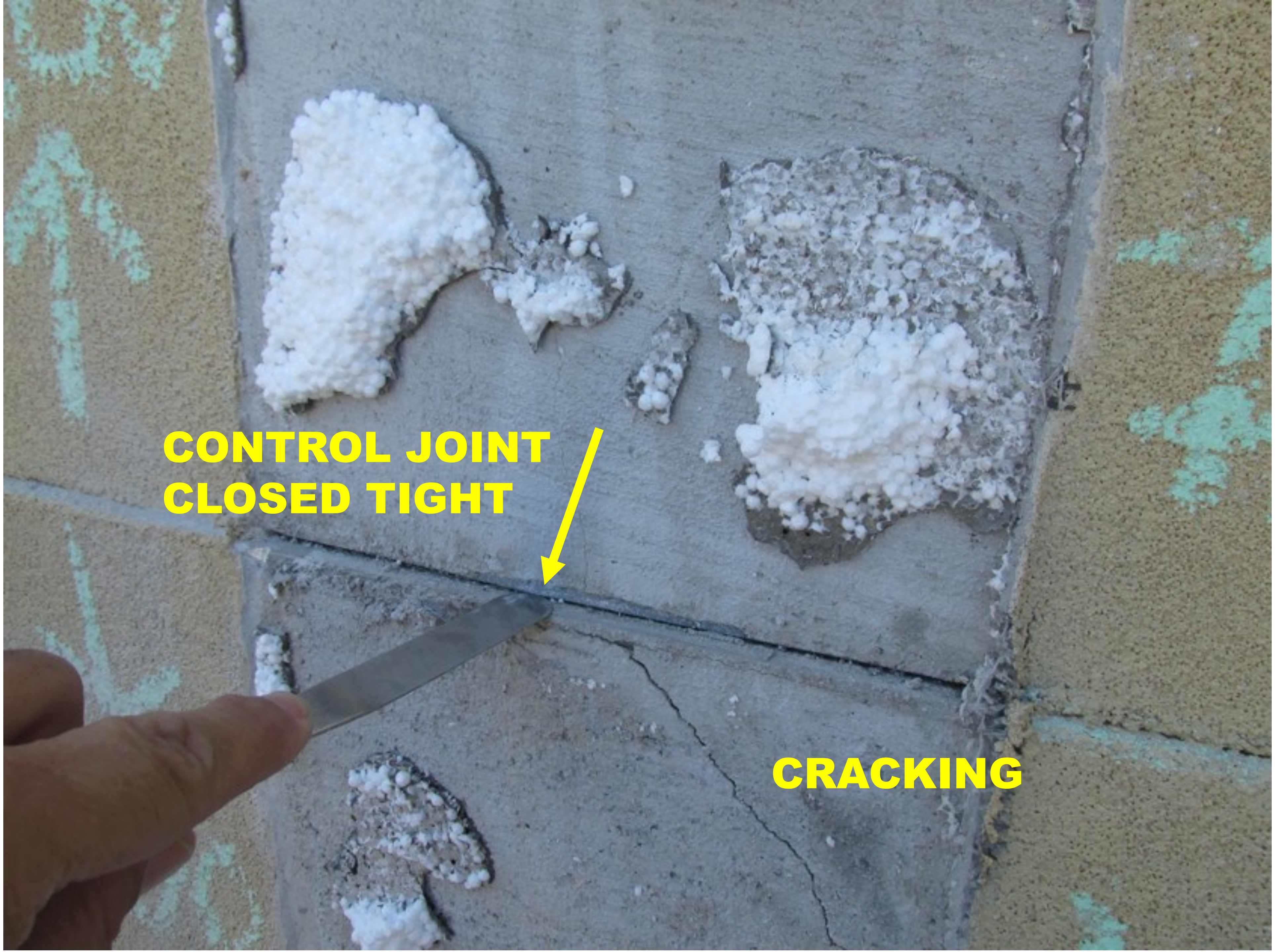

SEVERE
BUCKLING AT
CORNER NEAR
BALCONY
OPENING

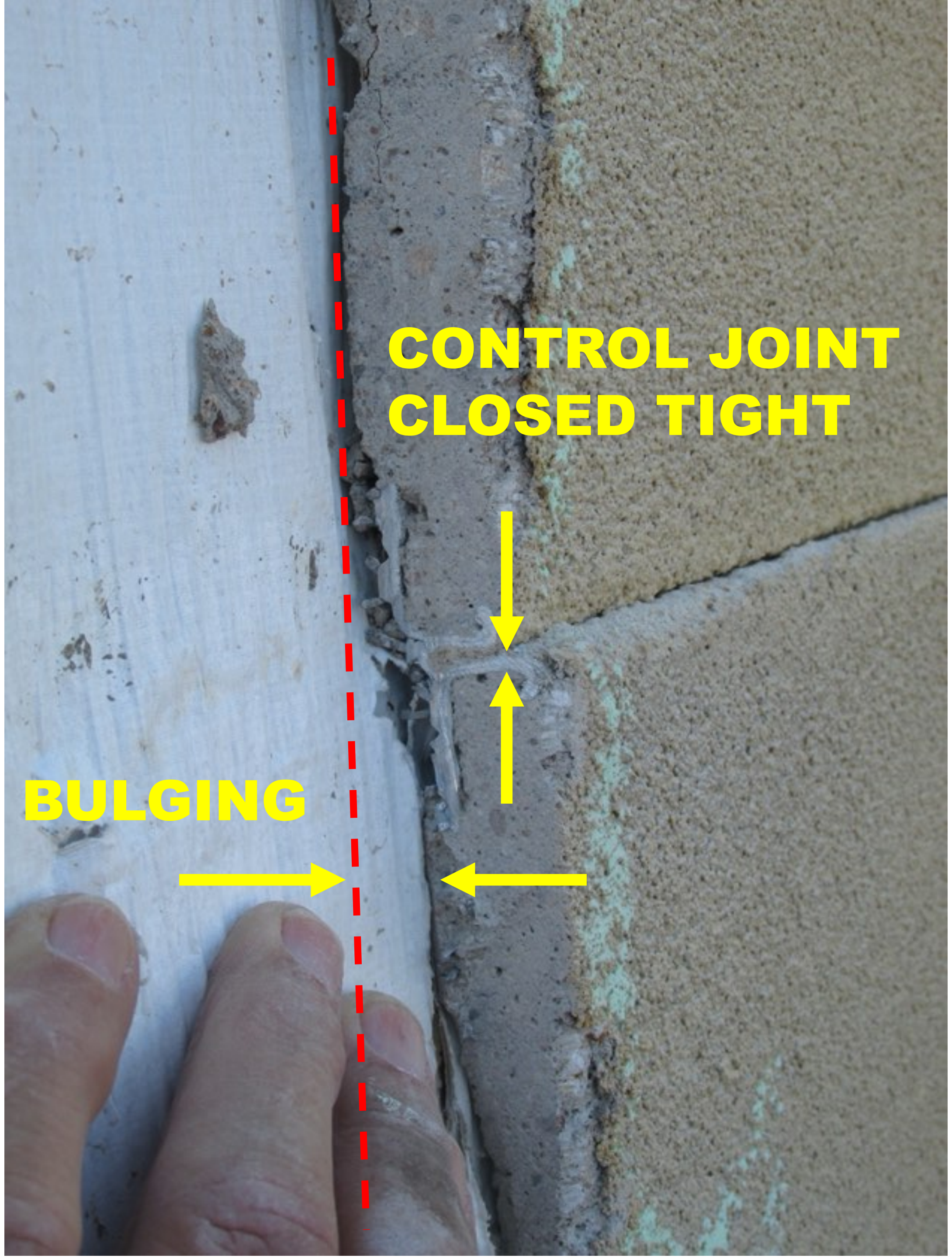

CRACKING OF PLASTER
ALONG PERIMETER BEAM

BUCKLING AND CRACKING OF EIFS ACCENT BAND AT FLOOR LINE

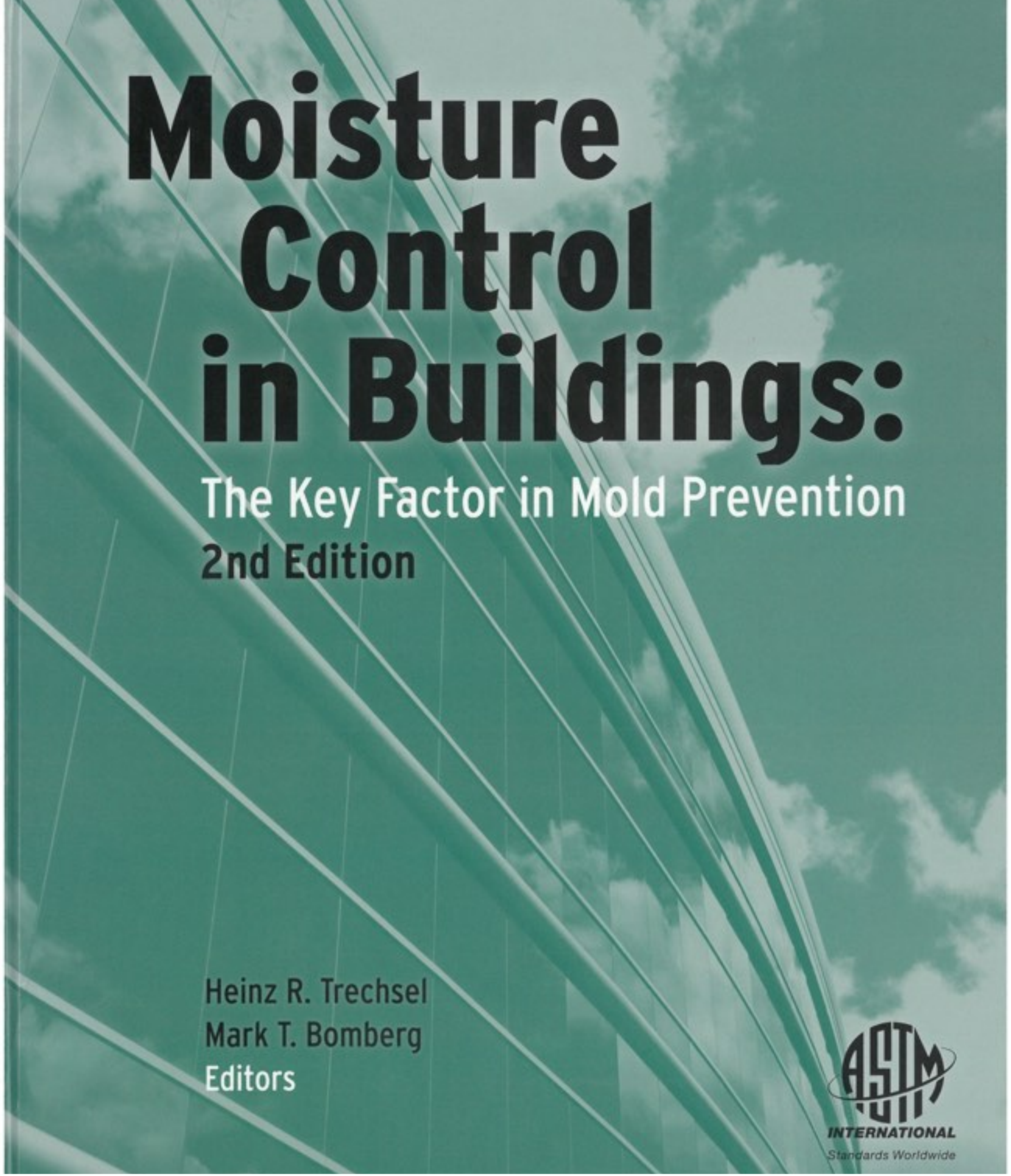

200
100
#1
N. Elev.


BULGING OF
EXTERIOR
SHEATHING AT
FLOOR LINE


CONTROL JOINT
CLOSED TIGHT
CRACKING


CONTROL JOINT
CLOSED TIGHT
BULGING


BOWING OF WINDOW SILL



Published in 2009;
1st Edition in 1994

20

Evaluation and Remediation of the Building Envelope for Existing High-Rise Buildings

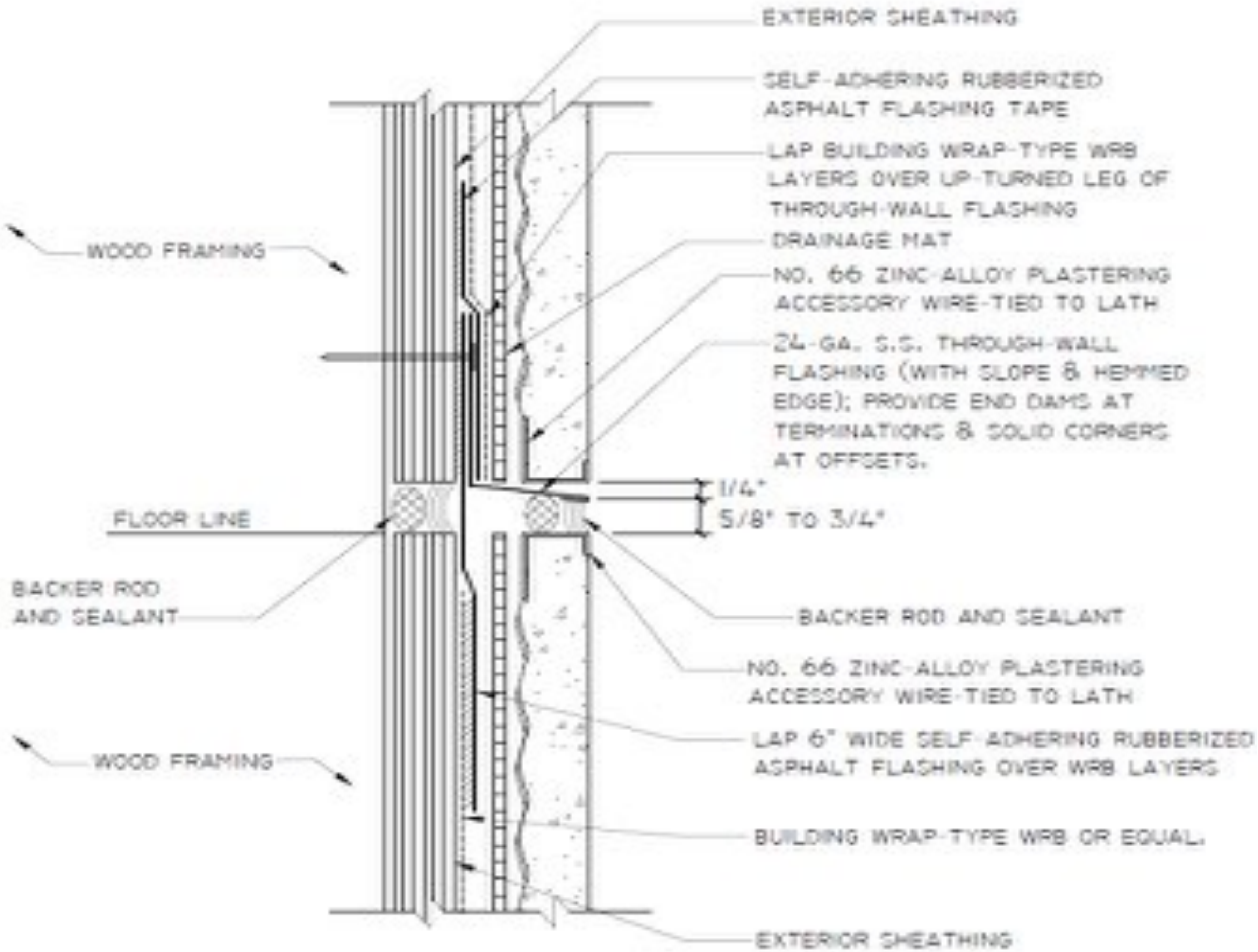
Warren R. French P.E. RRC, RWC[1]

Purpose

AS WITH ALL SPECIAL APPLICATIONS OF GENERAL principles, there are particular areas of concern when dealing with the design, construction, and maintenance of commercial, institutional, and high-rise buildings. This chapter will relate the principles previously stated regarding moisture migration, water vapor transmission, material properties, etc., to the special applications for these types of structures.

proper steps to use in developing and using such a program. ASTM International has developed and promulgated E2128 for evaluating water leakage in building walls, which may provide some guidance with respect to conducting such investigation [4]. In addition, pertinent magazine articles and compilations of technical papers have been written on this subject as well [5–10].

It should be noted that the scope and extent of exterior building envelope investigations for most high-rise build-


EXTERIOR SHEATHING
SELF-ADHERING RUBBERIZED ASPHALT FLASHING TAPE
LAP BUILDING WRAP-TYPE WRB LAYERS OVER UP-TURNED LEG OF THROUGH-WALL FLASHING
DRAINAGE MAT
NO. 66 ZINC-ALLOY PLASTERING ACCESSORY WIRE-TIED TO LATH
24-GA. S.S. THROUGH-WALL FLASHING (WITH SLOPE & HEMMED EDGE); PROVIDE END DAMS AT TERMINATIONS & SOLID CORNERS AT OFFSETS.
WOOD FRAMING
1/4"
5/8" TO 3/4"
FLOOR LINE
BACKER ROD AND SEALANT
BACKER ROD AND SEALANT
NO. 66 ZINC-ALLOY PLASTERING ACCESSORY WIRE-TIED TO LATH
WOOD FRAMING
LAP 6" WIDE SELF-ADHERING RUBBERIZED ASPHALT FLASHING OVER WRB LAYERS
BUILDING WRAP-TYPE WRB OR EQUAL.
EXTERIOR SHEATHING

CONCLUSIONS:

- Designers for cladding systems and building enclosure assemblies must take special care to properly detail these systems to accommodate differential movement between components that are subject to moisture shrinkage.
- This would include details for the exterior sheathing and fastening at floor lines to accommodate wind resistance and shrinkage.
- Particular attention should be given to cladding systems at floor lines, as well as at openings, such as windows, doors, and balconies, and at transitions, corners, and terminations.

CONCLUSIONS (con't.):

- **Designers for cladding systems and building enclosure assemblies may have to perform special calculations for the building official (and the project record) to establish that these considerations have be made.**
- **The BIG issues are the anticipated shrinkage, shortening, and differential movement that must be accommodated during and after construction.**
- **The entire cladding system should be looked at critically to anticipate where and how the cladding system might be adversely affected by these differential movements.**
- **No cladding system can accommodate this type of movement without special detailing.**

QUESTIONS?

This concludes The American Institute of Architects Continuing Education Systems Course

Warren R. French, P.E., RBEC, F-IIBEC

French Engineering, LLC

warren.french@frenchengineering.com