

# **Structural Assessment, Analysis and Retrofit Design of Old Unreinforced Masonry Buildings in the U.S. – A Comprehensive Guide**

**An Online Continuing Education Course for Engineers**

**Course Number: BD-3024**

**Credit: 3 Hours / 3 PDH / 3 CPD**

# Structural Assessment, Analysis and Retrofit Design of Old Unreinforced Masonry Buildings in the U.S. – A Comprehensive Guide

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## Chapter 1: Introduction to URM Structures in the United States

### 1.1 Historical Background and Prevalence

Unreinforced masonry—URM, if you're cool with acronyms—pretty much built the backbone of old-school America. Before concrete and steel strutted onto the scene, folks slapped up brick walls everywhere. Seriously, you name it: schools, courthouses, firehouses, warehouses, churches, even those slightly spooky old apartment buildings. If you've ever wandered through a downtown that looks like it belongs in a sepia photo, odds are you've brushed past a URM building.

Back in the late 1800s through the early '40s, these things were popping up all over. Brick and lime? Dirt cheap and everywhere. Construction? Straightforward. Labor? Also cheap. So, URM was basically the obvious move, especially in cities where everything had to go up fast and on a budget.

And here's the kicker—these buildings are still hanging around all over the place. The Northeast? Packed with 'em. Midwest and the West Coast? Same deal. Some are pristine, some are... well, let's call it "charmingly crumbling." Either way, they're part of the local DNA at this point. You'll spot URM buildings in:

- Old town squares and civic hotspots
- Pre-1950s school campuses (think: Hogwarts, but with more asbestos)
- Brick warehouse districts
- Military bases and train stations
- Churches and those classic mission-style buildings, especially down Southwest way

### 1.2 What Makes URM Structures Tick (Or, Not Tick)

Here's where the engineering nerds perk up. URM buildings are kinda wild—no modern bells and whistles. We're talking solid brick walls (sometimes hollow, but not in a fun way), stuck together with lime or weak cement. Floors and roofs? Usually, wood joists or steel beams just jammed into the walls—no fancy anchors, nothing holding them tight if things start shaking.

And get this: there's zero steel inside the walls. Nada. So, when you hit 'em with sideways force (like, say, an earthquake), the walls just... snap. No flexibility, no give. That's why they're legendary for falling apart when the earth moves.

Diaphragms? If you see a rigid one in a URM school, buy a lottery ticket—it's rare. Mostly, you get flexible wood, which is code for "not great in a quake." Other quirks:

- Super brittle—once things start to go, it's curtains
- The walls behave differently depending on which way the force hits them (engineers call this "orthotropic," but you don't have to)
- No real effort was made to tie walls and floors together, so the whole thing is structurally... eh, let's say "vulnerable" and leave it at that

### 1.3 Building Codes and Earthquake Epiphanies

People used to think these old brick beasts were totally solid—until 1933, when the Long Beach quake hit and basically said, "Guess again." After that, the West Coast got serious about updating building codes. Did every URM building get fixed up? Ha, not even close. Tons of them are still standing, untouched, hoping the next big shake skips their block.

Seismic codes started showing up for real in the '70s, but most states didn't force owners to retrofit old buildings. A few places—California, Utah, Oregon, Washington—put their foot down, but for most of the country, it's still "retrofit if you feel like it." Not exactly reassuring.

Lately, there's been a bit more awareness. School districts, city planners, and history buffs have started paying attention. You've got FEMA doing risk checks, California pushing for retrofits, ASCE 41 giving engineers some guidelines... but honestly, unless there's a law with teeth, a lot of these buildings are just crossing their fingers and hoping for the best.

### 1.4 Types of Cracks and Structural Deterioration You'll Actually See

URM buildings get old just like the rest of us, and you don't have to look too hard to spot the scars. Here's what usually pops up:

- Diagonal cracks running away from windows and doors. These bad boys usually point to quakes or the building settling in weird ways. Not cute.
- Walls that bulge or bow out, especially up top or at parapets—like the building's got a beer belly. Always makes you nervous walking underneath, right?
- Mortar joints are cracking along the lines, thanks to crappy bonding or the building expanding and shrinking with the weather. (Bricks and mortar are dramatic like that.)
- Mortar turning to dust or bricks looking chewed up from water sneaking in over the years.
- Layers of thick walls starting to peel apart, or you see gaps where the walls aren't tied together—looks sketchy, and, honestly, it is.

Honestly, if you don't know these signs, you're just guessing at what's wrong. Spotting them is step one before you even think about fixing stuff. We'll get into the "how to" later, promise.

## 1.5 The Engineering Imperative

Here's the deal: URM buildings are like that old classic car—gorgeous, but you wouldn't trust it on the freeway. We love them for the history, but let's be real, they're kinda a nightmare when it comes to safety.

Fixing these things isn't just about slapping on some new bricks and calling it a day. Engineers have to walk a tightrope: keep people safe, keep the building legal, don't blow the budget, and—oh yeah—don't ruin what made the place cool in the first place.

This whole course? It's built on that juggling act. As engineers, you're supposed to:

- Actually know what you're looking at—history, structure, all that jazz.
- Use up-to-date standards (like ASCE 41-23, if you're into that sort of thing) to figure out what the old gal can handle.
- Suggest fixes that work, won't break the bank, and don't trash the original character.
- Be able to defend your choices—why you did what you did—with solid logic and paperwork that won't get laughed out of a review meeting.

## Chapter 2: Methodology for Structural Assessment of URM Buildings

Alright, let's be real—checking out old unreinforced masonry (URM) buildings isn't just about poking around at crumbling bricks. First off, you gotta get a feel for what shape the thing's actually in, but you also need to dig into how people slapped it together in the first place. Spoiler: these aren't modern glass-and-steel skyscrapers. Most of the time, there's basically zero paper trail, no fancy rebar hiding in the walls, and half the construction choices make you go, "Wait, they did what?"

So, you're not just playing engineer—you're part detective, maybe even a bit of an archaeologist. You've got to snoop around, run some tests, figure out if the materials are still doing their thing, and try to piece together how all the parts interact (or don't). Usually, you're looking at four main steps: a quick once-over, poking and prodding the materials, digging into the structure itself, and then seeing how everything works together. It's messy, but honestly, that's half the fun.

### 1. Preliminary Survey and Visual Inspection

Alright, so, step one—yeah, the biggie—when you're sizing up some ancient, battered brick building with zero rebar holding it together? You gotta start with a good old-fashioned look-around. And I don't mean just strolling through, snapping a few pics for Instagram. We're talking a hands-on, eyes-wide-open hunt for trouble. You need sharp instincts, a half-decent knowledge of how folks used to slap these things together, and a knack for spotting weird stuff others might miss. Basically, channel your inner building detective. Purpose of the Visual Inspection

The purpose of this inspection is to develop a comprehensive understanding of the building's current physical condition, identify visible signs of structural distress, and begin forming hypotheses about how the structure behaves under gravity and lateral loads. It also helps the engineer prioritize areas for detailed testing and modeling, ensuring that time and resources are used efficiently.

## What to Look For

Alright, let's cut through the boring checklist vibe and talk real. When you're eyeballing a URM (unreinforced masonry, for those not living in a codebook) building, here's what actually matters:

- Crack Patterns

Cracks in brickwork? They're like the building's diary entries, and yeah, they're dramatic. Vertical cracks—think of these as the building slumping or shrinking. Diagonal cracks, especially around the corners or windows, usually scream, "Hey, we just got rocked by an earthquake or some gnarly wind!" Horizontal cracks near the floors or up by the parapet? That's more like the walls trying to bust out because they're not anchored down right. Each crack's got its own little horror story.

- Bulging or Out-of-Plane Weirdness

If the wall's starting to bow out, even by a hair, that's no joke. It's a neon sign flashing: "We're losing it!" It could be the bricks aren't sticking together anymore, or maybe water's gotten in and frozen, busting things up. Either way, if there's an earthquake, that's the spot you do not want to be standing near.

- Wall Separation

If you spot walls pulling away from the floors or the roof—yeah, that's a bad time. Old buildings? They usually skipped the whole 'anchoring' thing. So when stuff starts shaking, those floors are basically just along for the ride.

- Mortar Condition

Mortar's like the glue holding your Lego castle together. If it's turning into dust or crumbling when you poke it (and yes, you should poke it), the wall's losing its mojo. Don't trust it to hold up under pressure.

- Parapets and Chimneys

These are the first to peace out in an earthquake. Wobbly bricks, cracked tops, or chimneys that just look sketchy? Pay attention—these bits are notorious for collapsing when you least want them to.

- **Moisture and Funk**

Water's the silent killer here. White salty stains (efflorescence), weird green patches, mold—if you see any of that, especially around busted gutters or missing flashing, you've got problems. Rot and brick don't mix.

- **Old Repairs or Dodgy Fixes**

Spot any weird patches, obvious steel bolted into the wall, or sections that look like they've been Frankensteined back together? Sometimes, repairs hide more issues than they fix. Don't just trust the facelift.

- **Roof and Floor Connections**

Take a gander at how the floors and the roof meet the walls. Notice any beefy anchors or plates? Or is the floor sagging like a teenager's jeans in the '90s? If there's no visible connection, or it looks overloaded, that's a weak point just waiting to fail.

Bottom line: URM buildings aren't subtle about their problems. They leave clues everywhere—cracks, bulges, weird stains. Just gotta know where to look and not get fooled by a fresh coat of paint.

## Tools and Techniques

Honestly, nothing beats a seasoned engineer's eyeballs—those folks can spot trouble like nobody's business. Still, there's a whole toolbox of gadgets that make the job easier (and save a few knees and necks):

- Plumb bobs and those fancy laser levels? They're clutch for catching walls that are doing their best Leaning Tower of Pisa impression.
- Measuring tape and crack gauges—oh yeah, gotta get nerdy about those cracks. How wide? How long? Patterns? Snap a pic or jot it down; otherwise, you'll forget by lunch.
- Drones aren't just for YouTubers—toss one up to peek at sketchy chimneys or roof bits you'd break your neck trying to reach.
- Your phone's camera (or some annotation app, if you're feeling high-tech) is perfect for grabbing quick shots and scribbling notes before you forget what you even looked at.

And hey, if you can dig up old blueprints or plans, you're halfway to detective status. Overlay your damage notes right on those drawings. No plans? No problem. Most engineers end up sketching floor plans on paper napkins or whatever's handy, marking where stuff's going wrong. Not exactly fine art, but it gets the point across.

## Documentation and Interpretation

Every observation should be recorded with both a **narrative description** and a **visual reference**—ideally, color-coded on annotated floor plans and elevation diagrams. Cracks are typically ranked by width and

activity (e.g., active vs. stable). Wall conditions can be scored or labeled (e.g., "severely deteriorated," "moderately cracked," "no visible distress") to inform later engineering judgment.

The goal is to **develop a working model in the engineer's mind**: How is this building carrying its loads? Where are the vulnerabilities? What would happen during an earthquake?

This is the point where engineering experience becomes invaluable. A seasoned engineer can often infer the likely load path and failure mechanisms based solely on visible signs. Still, no final decisions are made at this stage—it's about developing an informed plan for testing and modeling.

*You can review the Field Inspection Checklist for URM Buildings in Appendix A at the end of the course.*

## 2. In-Situ Material Testing and Investigation

Alright, picture this: you've finished with the hard hat in hand, jotting down all those weird cracks and peeling paint. It's the real fun—time to roll up your sleeves and get to work. The inspector's peeking out at you.

Honestly, with all the records. Half the fun of in-situ tests isn't just poking around with instruments, it's figuring out if the place will stay standing.

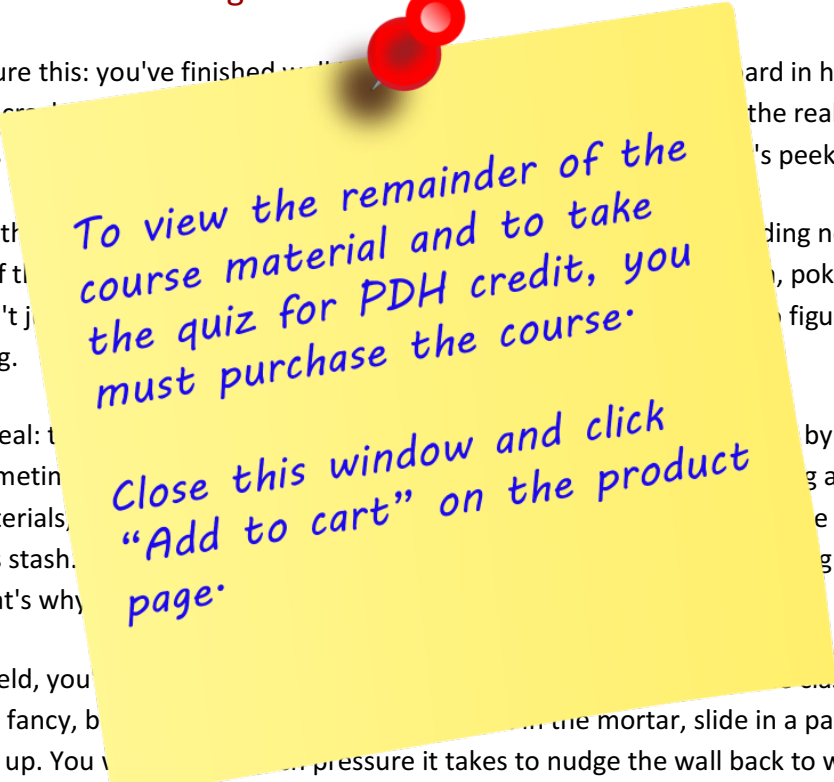
Here's the deal: over the decades, sometimes random materials, like a bootlegger's stash. It's by different crews over time, all sorts of nonsense—things that have been forgotten. It's like getting news for the wrong reasons. That's why

Out in the field, you'll see classics like the flat-jack test. Sounds fancy, but it's just a matter of mortar, slide in a pancake-shaped jack, and pump it up. You measure the pressure it takes to nudge the wall back to where it started. That number? Tells you how stressed out (literally) the bricks are and how much flex they'll give before things get dicey. Super handy when a wall looks fine but might actually be one bad day away from giving up, especially if someone messed with it in the past or the load isn't spread out right.

So yeah, don't trust a pretty brick face—dig in, test it, and get the truth.

Alright, let's ditch the stiff lab-coat language and talk straight.

So, around the building, you've got these pretty basic but surprisingly handy tools for checking how tough the bricks and mortar really are. Ever seen a Schmidt hammer? Looks like something you'd use to



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