WHEN THE EARTHQUAKE SHAKES, MAMA YOU GOT TO MOVE

I recently visited San Luis Obispo, CA and spent some time strolling about downtown. I came upon the following placard posted conspicuously on the front of an older building.

Here is the building from across the street. You can see the placard just to the left of the tree between the entry doors.

The placard struck me as funny for several reasons:

1. This town and every other town up and down the west coast (earthquake country) is full of unreinforced masonry buildings (URMs).

2. This was the only such placard I saw in San Luis Obispo, or for that matter, in any town, ever.

3. The placard presupposes that a shopper will be prescient enough to know when the earthquake will hit and thus will avoid being in or around at that time.

So we're left with a few questions:

A. Why bother with the placard?

B. How much risk is there, really, with unreinforced masonry buildings?

C. What can be done to mitigate the risk?

Before I jump into this article, I am compelled to tell you that I'm not picking on San Luis Obispo. I just happened to spend a couple sunny days there recently with my wife and college-bound son. We had a wonderful time – great hotel, great restaurants, shops, and the college was magnificent. I had my camera and did what I do while my wife did what she does: shops. This article could have been written about **any** town with old buildings. That said, here are my answers. I'll start with "B."

How much risk is there, really, with unreinforced masonry (URM) buildings?

No one can say, exactly, because each building's risk depends on many variables, such as: direction from which the earthquake comes; magnitude of the earthquake; how many windows and doors the building has; how well the roof is connected to the walls; how thick the walls are; how many interior walls there are; whether or not there's a 2nd floor; quality of construction; etc.

We do know for sure that when earthquakes hit, unreinforced masonry buildings take a severe beating and are generally the first to fail. There are two reasons. First, earthquake forces on a building are directly proportional to the building's weight. Masonry weighs a lot as compared to, say, wood, thus generates a lot of seismic force. If the building isn't strong enough to resist that force it will fail. Second, unreinforced masonry is brittle; brittle being the opposite of ductile. URM has no mechanism to take the tensile (a.k.a. tension or pulling) component of back-and-forth rocking associated with earthquakes and strong winds. When a building sways to and fro, portions alternate between tension and compression. Masonry is great at taking compression but lousy at resisting tension. It is for this reason that rebar is required per current building code.

As an example, here is a new masonry building in San Luis Obispo. This looks to me like an elevator shaft for a proposed bank.

Note the rebar projecting up from nearly every masonry cell. All that rebar isn't there because the engineer has a love affair with steel. No, it's there because the code requires it. Engineers, myself included, take a lot of heat from masons and building owners who've never themselves designed a masonry building per the 2009 IBC.

Back in the day, building codes didn't exist and / or didn't require steel reinforcement in concrete or masonry. Here are some URM examples.

This building was constructed in 1925 and has been through several earthquakes. The placard at the corner tells the building's history. The front wall has nearly zero lateral resistance because it is

mostly doors and windows. It is so far out of compliance with current code it's staggering. At each window corner there's tell-tale cracking from sideways movement in past earthquakes, like so...

Previous owners have attempted repair via regrouting, which, while it may keep weather and vermin out, is structurally worthless.

Here's another example of a high-risk URM building. Again, the lower front wall has approximately zero lateral resistance. And worse, there's a lot of weight on that wall from the upper story. This condition is called a soft story.

Here's a whole lotta' URM. If the earthquake forces act parallel to the wall, this building will likely survive because there's so much wall to resist the in-plane forces. If the earthquake forces act perpendicular to this wall, i.e. parallel to the windowed storefront around the corner, the risk of failure goes way, way up. Maybe there should be a placard that says, "Earthquake Warning. Do not be in or around this building in a north-south-acting earthquake. East-west-acting earthquake, Shop on!" Also, interesting door way up there.

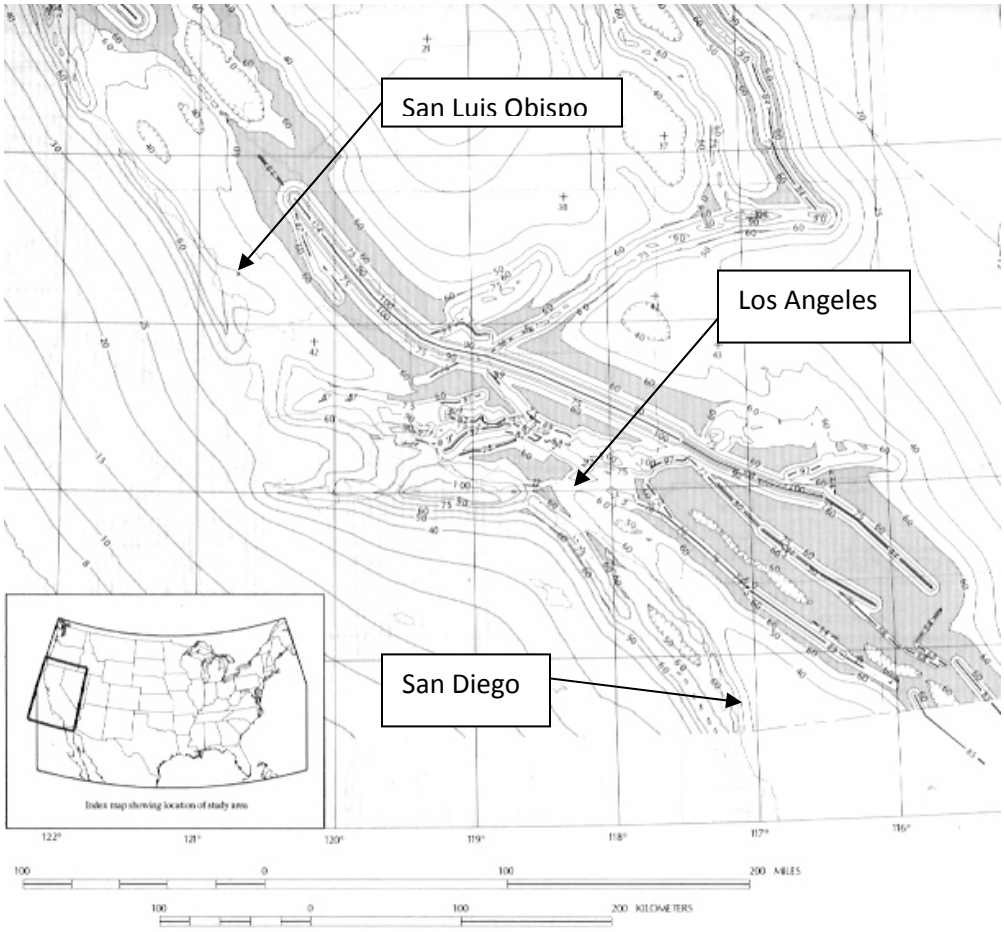
This is the mission at San Luis Obispo. It is made from UA (Unreinforced Adobe), which is mud and straw. How in the world has this survived 239 years? I poked around inside and did note some

earthquake-induced wall cracking. But mass is still held here regularly and there's nary an earthquake warning sign to be found.

San Luis Obispo (SLO) is in earthquake country to be sure, however, it's not as close to a known active fault as other places, such as parts of San Francisco or San Bernardino. SLO is some 40 miles west of the San Andreas Fault, close enough to jar your dentures but not what I'd call an extreme hazard area. The survival of the above URMs is testament to that. Take a trip to a town on the San Andreas Fault and visit a museum there. You'll find plenty of historic photos showing crumpled URMs from the various earthquakes over the years.

How to tell where your town lies relative to earthquake faults? Get a copy of the International Building Code (IBC) or the International Residential Code (IRC) and check out the maps therein. Here's a copy of what you'll find in the 2009 IBC:

[Courtesy, International Code Council. IBC, 2009]

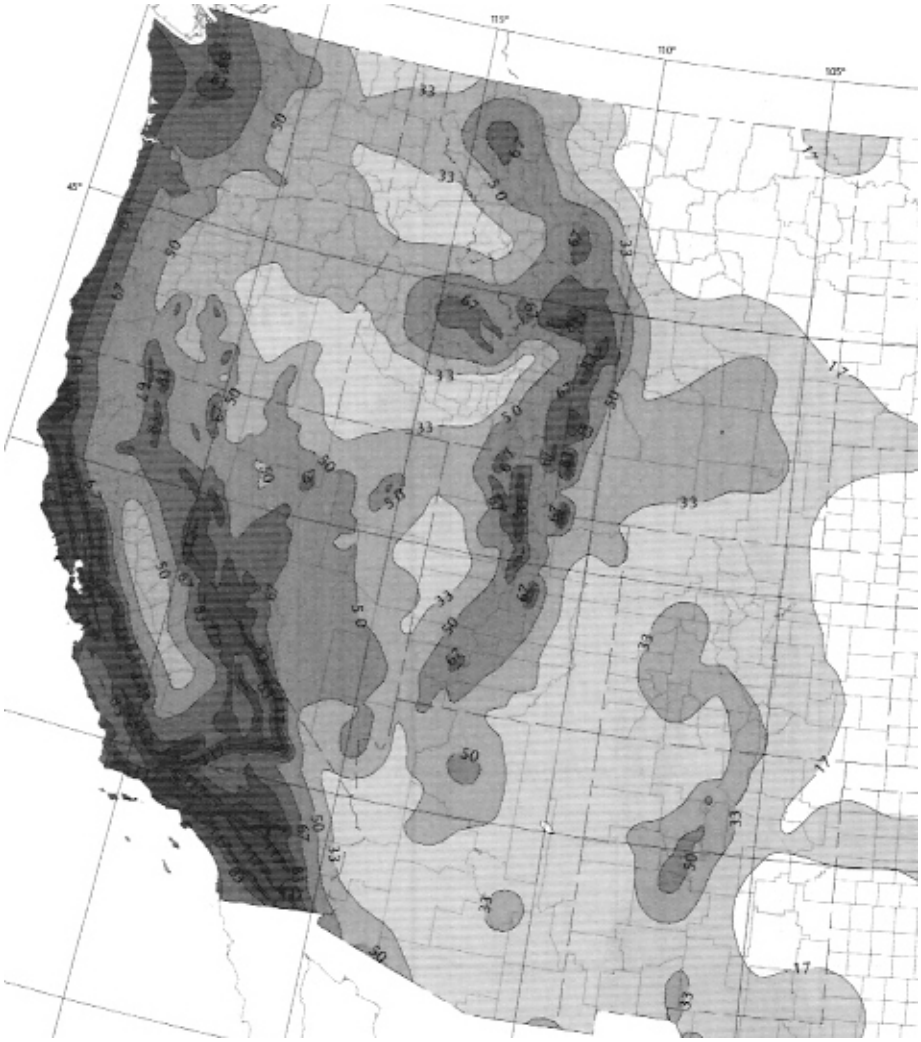


This is a blow-up of the south California coast. If I hadn't added the labels, could you find LA? San Diego? San Luis Obispo? They're there, but like most things in the IBC, finding them is nearly impossible. (I've written about the obfuscating quagmire that is the International Code on more than one occasion, see my blog. But I digress.) If you're a skilled cryptographer and find your city on one

of these maps, you can tell the relative earthquake risk by the magnitude of the contour line running through / near it. Those lines represent the expected earthquake ground acceleration; the higher the number, the greater the earthquake force. The dark lines are coincident with known active faults. The shaded areas have “a constant spectral response acceleration of 60% g,” i.e. pretty dangerous.

The I**R**C makes life a little simpler. Here’s a copy of the western United States from the 2009 version:

[Courtesy, International Code Council. IRC, 2009]



At least you can find yourself with this, and, hallelujah, it’s fully shaded in hues of gray. The darker shading corresponds to higher ground accelerations and thus higher earthquake forces.

In my opinion the most important factor in evaluating a URM’s risk is its location. If such a building is, say, within 5 miles of an active earthquake fault, I’d classify it as an extreme risk. The URMs in

San Luis Obispo, I'd call high risk. If I happened to be inside any URM and felt the ground begin to shake, I'd do like the old Led Zeppelin song says about the breaking levee: *move*.

Which brings us to question two:

Why bother with the placard?

I suppose if I owned an unreinforced masonry building and was an attorney I might put up such a placard. But since I'm not an attorney I don't think I'd bother. Considering all of the structurally inadequate buildings and bridges out there – hundreds of thousands of them - many owned by public agencies - that have no disclosure concerning their hazard, I don't see how a person could assume liability for a URM that fails in an earthquake. But, again, I'm no attorney.

From an ethical standpoint, if I owned a URM in a seismically active area, I would take steps to bolster it. To heck with the placard. Instead, actually do something. Which brings us to the third and final question:

What can be done to mitigate the risk?

I would argue that there is no practical way to bring a URM into compliance with current building code – even though the code sometimes requires it. I know it's supposedly done all the time, and in fact, I've designed such upgrades myself. But the truth is, if the ground really gets with it, the URM will likely crumble and fail around the connections to the strengthening elements. Let's have a look at an example earthquake retrofit in San Luis Obispo.

Here is a steel moment frame constructed in the plane of the front window wall. If the ground shakes parallel to the front wall, this frame will resist racking in that direction. If the ground shakes the other way, this frame does very little – other steel frames perpendicular to this one are needed.

A moment frame is only as good as its connections to the upper horizontal (roof or floor) diaphragm and to the ground. If either of those connections are weak, the very expensive steel frame will do no good. The building will fall down around it.

Same building different window wall (this corner building has two.) This frame is a two-bay bent whereas the previous one is a one-bay bent. The term “bent” means structural frame though why that is I do not know. Bent? How about “straight” or “in-plane strong”? I didn’t measure but estimate these steel columns and beams are about 12” deep and 6” wide. Pretty beefy (read expensive) for this light-framed building.

Same building but this is an interior unreinforced masonry wall. The vertical steel tubes are intended to resist out-of-plane seismic forces. When the ground shakes in the direction perpendicular to this wall, the wall wants to bend inward and outward like a sail flapping in the wind. Without steel reinforcement there is little to keep the bricks from falling out. This fix definitely helps, however, the tubes are spaced about 6’ apart which doesn’t do much for the bricks in between. Also, they’re bolted to the wall with rotohammered expansion bolts. In a strong earthquake, there’s not much to keep the brittle masonry from crumbling around the bolts.

Same building, yet another moment frame – a one-bay bent, but this time it's located near the middle of the interior space. This building owner spent a lot of money with his seismic upgrade.

Even though I may seem critical of the above retrofit, I think it's a darned good one. Does it bring the building into compliance with current code? In my opinion, no, though the design engineer and jurisdiction might say differently. I will say this, however, should an earthquake rock San Luis Obispo, this is the building I would want to be in if I had to be in a URM. I'd stand right under one of the bents and dodge falling things.

There are other methods of bolstering URM. Wood shear walls are an excellent choice. Of course, they're walls and have a way of wrecking the openness of a retail space. I've also designed and seen steel rod X-braces. They're generally more efficient (read less expensive) than moment frames but you have to be okay with diagonal rods running through the space.

Regardless of the method used, the most important things are the connections to the upper and lower floors and / or roof. Fail at those and come the big one, you'll have a very expensive structural element poking up through your smoldering rubble.

In conclusion, I think an earthquake warning placard is kind of silly. However, a person would do well to understand their risk when entering an unreinforced masonry building – especially one near a known seismically active fault such as the San Andreas. Truth be told, when I do that, my danger senses are on full tingle. I glance around nervously half expecting bricks and mortar to explode at me

from every direction. My wife thinks I'm nuts but when the earthquake shakes, if I'm anywhere near her, she's one mama that will have to move. I'll be darned sure of that.

This article lives at my blog at www.ConstructionCalc.com. I welcome all comments there or on my forum at the same website. Feel free to forward this article to anyone who may find it useful.

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