Times Standard

Not My Fault: Ignoring fatigue can lead to consequences in submersibles or buildings

Lori Dengler for the Times-Standard
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Failed rebar in bridge support near Kaikoura, New Zealand 2017. Repeated loading - unloading cycles during the 2016 M7.8 earthquake contributed to the failure. Photo from EERI Learning from Earthquakes.

I've been watching the Titan disaster play out. The small submersible had likely already imploded, crushed by the immense pressures of the deep ocean by the time it was first reported missing. We may never know the full story of what happened, but one thing jumps out: cyclic fatigue.

Cyclic fatigue means damage that occurs when repeatedly stressing and relaxing a material. No matter what the material, the more times you squeeze or stretch it, the weaker it becomes. Titan, owned and operated by OceanGate, a private adventure tourism company, had made 13 trips in the past two years to the site of the Titanic. Each trip produced incredible pressures on the carbon fiber – titanium hull. And each return to the surface reversed that pressure stressing the hull in the opposite direction.

Fatigue is a well-known property of materials under stress. Microscopic cracks form in response to loading. In repeated loading – unloading cycles, the cracks grow. At some point, the strength

of the material may be compromised, and crack growth accelerates. The result is often rapid failure at stress levels far below the strength of intact material.

I am not material science expert but am familiar with stress loading, fatigue, and failure through working with earthquake engineers. Structures experiencing strong earthquakes are also repeatedly stretched, compressed, and twisted.

Seismic forcing is complex. The shape and size of the building may resonate and amplify the forces to higher levels to those on the ground. The duration of shaking can produce fatigue as structural elements are repeatedly moved in one direction and then another. Aftershocks further compound the problem; a structure that withstood the main quake may fail in a smaller one because some of the structural elements have been compromised.

Other forces are also at work on structures such as temperature changes, wind, and the movement of people, cars, or other items. Structural engineers must consider both expected and unexpected forces. The 1987 Golden Gate Bridge Walk, in celebration of its 50-year anniversary, is a case in point.

Traffic was stopped and about 300,000 people were allowed onto the bridge before officials noticed a distinct flattening. Suspension bridges like the Golden Gate owe their strength in part to the upward arch that counteracts the gravitational pull on the structure. The center arch sagged seven feet with the unexpected additional weight. There were still a half-million people wanting to walk the bridge when pedestrian access was halted.

In building structures, designers must take into consideration all potential forces and sometimes one isn't aware of all of them until after the fact. All structures must withstand the constant downward tug of gravity, or they won't stand up in the first place. Dynamic forces like seismic waves are rarer and easier to ignore until an earthquake occurs, and it is too late.

California is a leader in earthquake resilient design, building codes, and enforcement. That's not surprising as we've experienced more damaging earthquakes than any other part of the U.S. The 1933 Long Beach earthquake ushered in earthquake-specific design requirements. Only a magnitude 6.4 (the same as last December's Ferndale earthquake), the earthquake killed 120 and caused nearly a billion in damages in today's dollars. It was the 120 badly damaged brick school buildings that sparked legislation. Fortunately, the earthquake occurred just after school and most children had left, but the scale of the devastation could not be ignored.

The Long Beach earthquake glaringly pointed out the fragility of URMs (unreinforced masonry structures) and began California's quest to require reinforcement or removal. Initial efforts focused on schools and hospitals but in 1986, the Unreinforced Building Law was enacted requiring every County to inventory and develop plans for reducing the URM threat. Estimates of its effectiveness vary; a Seismic Safety Commission report in 1995 reported three-quarters of California communities were in compliance with the law but that progress was slow and the financial barriers high.

In Humboldt County, more than two dozen URMs were identified. With this year's demolition of the Lloyd Building, almost all County URMs have been retrofitted or removed. But URMs aren't the only structures at risk during earthquakes. The most vulnerable structures in our

M6.4 last December were single family homes and mobile homes that were not adequately secured to foundations.

Any structure built before 1960 is likely to have foundation problems unless reinforced. Our first Humboldt County home was perched atop post and piers, a common and inexpensive construction solution to get the structure off of damp ground. Unfortunately, each post/pier will respond differently during shaking causing the structure to tilt or sag. The good news is that this damage will rarely kill you; the wood structure above is still mainly intact. The bad news is your home won't be safe for occupancy and is expensive to repair.

When our son purchased an 1893 home, his first step in rehabilitating the structure was to replace the post and pier foundation with a continuous perimeter foundation (Not My Fault 9/12/2019). But the cost of such a retrofit is out of reach for many people. If you own your own home, you may be eligible for California's Brace and Bolt Program (Times-Standard 1/25/23), which only recently became available for all of Humboldt County.

Last Sunday was not the first indication of problems with OceanGate's submersible. Titan showed evidence of cyclic fatigue problems in 2020, prompting repair and reinforcement. By operating in international waters with few regulations, there were no certification or testing mandates. In contrast, the deep-ocean research vessel Alvin, first launched in 1964, has made over 5000 dives, some deeper than the Titanic. Operated by the U.S. Navy in cooperation with oceanographic institutes, it must meet stringent requirements before and after every dive.

It is possible to safely explore the depths by following good science and engineering protocols. The same can be said for living in structures in earthquake country. It costs money, time, and energy. Waiting until after disaster strikes is too late.

To learn more about California's Brace and Bolt Program visit https://www.earthquakeauthority.com/Prepare-Your-House-Earthquake-Risk/Brace-and-Bolt-Grants

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Lori Dengler is an emeritus professor of geology at Humboldt State University, an expert in tsunami and earthquake hazards. The opinions expressed are hers and not the Times--Standard's. All Not My Fault columns are archived online at https://kamome.humboldt.edu/taxonomy/term/5 and may be reused for educational purposes. Leave a message at (707) 826-6019 or email Kamome@humboldt.edu for questions and comments about this column. Downloadable copies of the North Coast preparedness magazine "Living on Shaky Ground" are posted at https://rctwg.humboldt.edu/prepare/shaky-ground.