

# SILO<sup>VS</sup> EARTHQUAKE

## WHY SEISMIC DESIGN IS CRITICAL FOR GRAIN STORAGE SILOS

Some of Earth's most fertile soil can be found on shaky ground. For manufacturers of grain storage silos and other agricultural structures, failure to take seismic activity into account can lead to more rapid deterioration of materials on-site and catastrophic structural failure in the event of an earthquake.



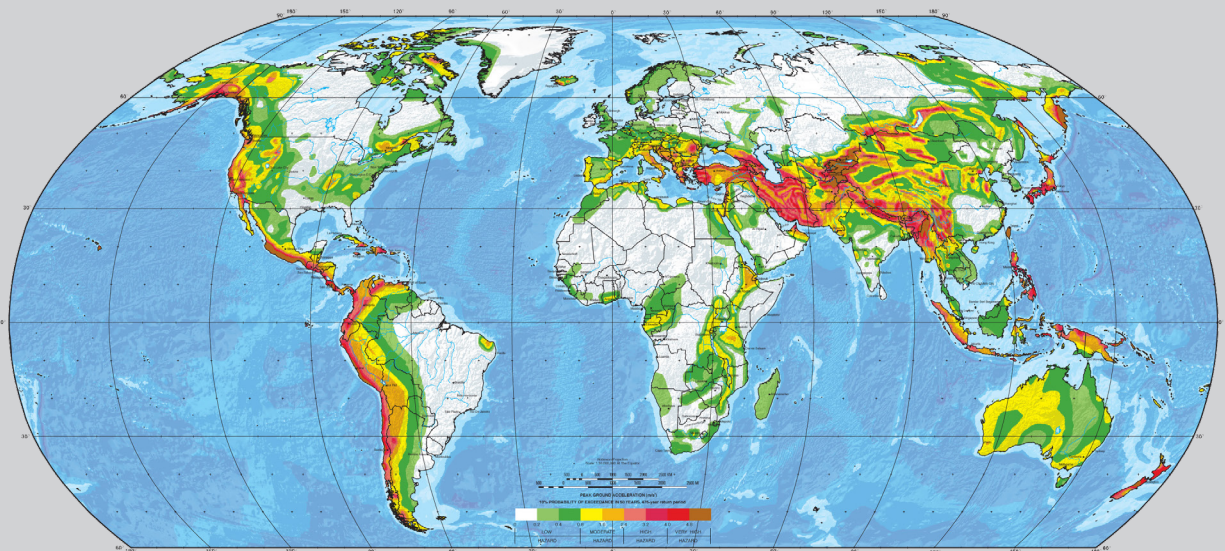
First, it is crucial to understand the terminology of seismic design. Though often used interchangeably, the terms “seismic zone” and “seismic hazard zone” actually refer to two different things. According to the United States Geological Survey (USGS), a seismic zone is an area where earthquakes are common. A seismic hazard zone is an area that is in particular danger due to earthquakes. In other words, seismic

zones simply tell us that the earth moves more frequently in certain areas, whereas seismic hazard zones describe how much damage this movement tends to cause.

Effective storage system design must account for seismic forces that the silo could be subjected to when full or partially loaded. Grain is a semi-flowable material which does not necessarily move inside the silo during a seismic event. Rather than moving inside the silo, it somewhat dampens the seismic forces.

The earth moves under a silo in an earthquake. The mass of the silo and the stored material resists this movement. As a result, the silo walls must resist these multidirectional forces.

## GLOBAL SEISMIC HAZARD MAP



Produced by the Global Seismic Hazard Assessment Program (GSHAP), a demonstration project of the UN/International Decade of Natural Disaster Reduction, conducted by the International Lithosphere Program.

Global map assembled by D. Giardini, G. Grünthal, K. Shedlock, and P. Zhang - 1999



In seismic design, the designer assumes that the lateral earthquake force acts about the centroid of the mass inside the silo. The taller the silo, the higher the centroid of mass. Earthquake forces act on the silo as a cantilever beam, so the forces are smallest at the top and greatest at the bottom of the silo. The movement of the earth under the silos creates seismic shear forces, which must be resisted both by the silo and by its foundation. Thus, the greater the seismic load on the silo (a function of the silo's height and diameter, and of the earthquake force), the larger the compression forces on the vertical stiffeners on one side of the silo and tension forces on the opposite side. Because the movement under the silo can come from any direction, all the stiffeners and anchors must be designed for the seismic force. Large anchors are usually required on silos designed for seismic loads.

“In higher-activity seismic zones, we scale up from a single stiffener to use as many as three laminated stiffeners instead,” explains Randy Peterson, Engineering Manager for SCAFCO Grain Systems Company in Spokane, Washington, USA. As the ground heaves and the contents shift inside a silo, the ongoing integrity of the structure rests largely on the ability of the stiffeners to transfer the load to the foundation. This is why some designs call for additional stiffeners only toward the bottom of the silo, as the area nearest the base is the most critical in terms of load transfer.

When transferred energy reaches the base of the silo, the importance of anchor bolts becomes paramount. Randy notes that seismically-active areas call for larger anchor bolts, and more of them. Refer to Figure 1. By incorporating these additional heavy-duty bolts, engineers are able to mitigate the tendency of a silo to come loose from its foundation and catastrophically destabilize during an earthquake, as seen in Figure 2.



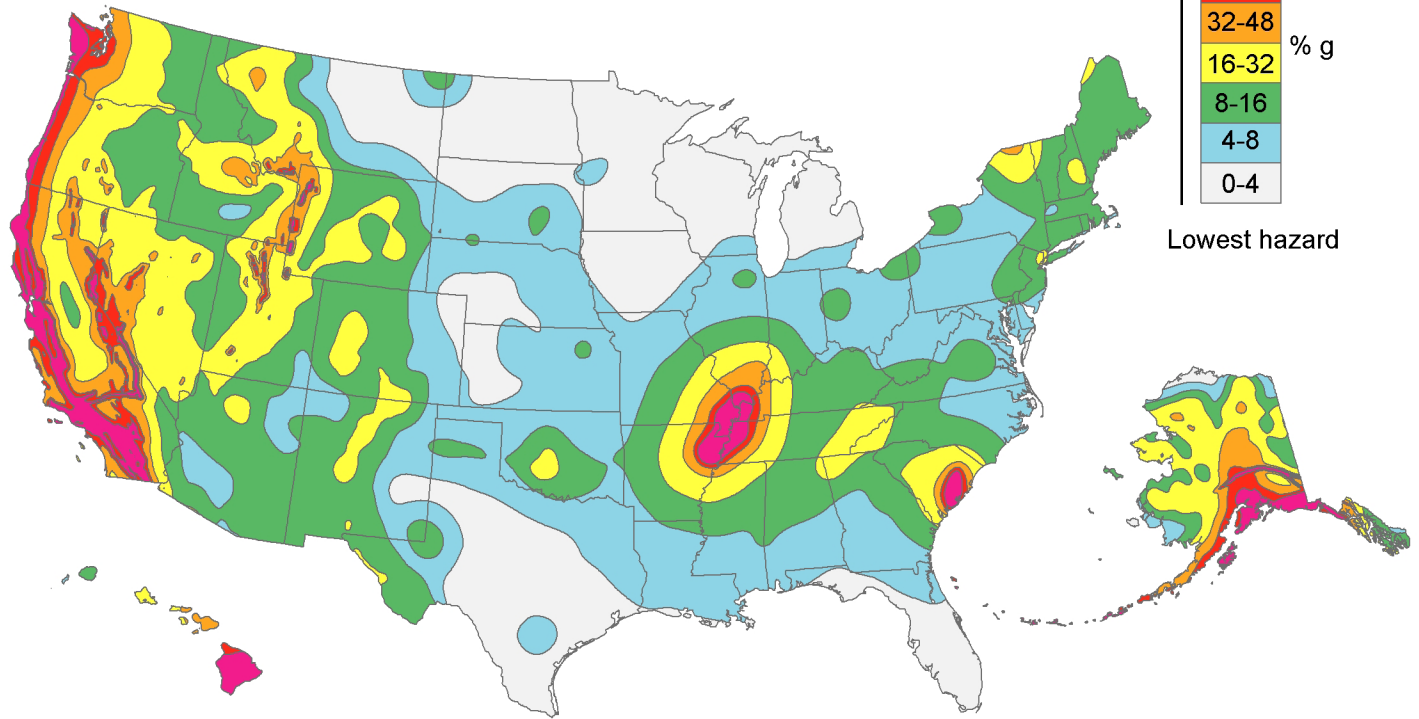
Figure 1: Seismically-designed stiffeners and anchor bolts from SCAFCO Grain Systems kept this silo standing through an 8.6-magnitude earthquake in Chile.



Figure 2: On the same site during the same earthquake, a competitor's components failed. The silo collapsed.



## United States Geological Survey's National Seismic Hazard Map.



As an integral part of the seismic design process on a new project, engineers turn to one or more readily-available standards to determine the seismic forces at play. The Uniform Building Code (UBC) seismic zones provide criteria at a regional level suitable for projects throughout the world. The International Building Code (IBC) Seismic Design Categories, meanwhile, offer more specificity in providing data on the seismic activity of individual ZIP codes in the United

States. The USGS National Seismic Hazard Map also provides domestic data on the prevalence of earthquakes in certain regions.

In addition to earthquakes, silos can also be designed to withstand strong winds and even endure hurricanes up to Category 5 – approximately 186 miles per hour (300 kph). As in the case of earthquake resistance, however, their durability still depends heavily on the skill of the designer and the

suitability of the design itself to the geographical context in which the storage system will be used.



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