Seismic shaking: attenuation with increasing depth below the surface

Description: World wide there are thousands of kilometres of tunnels, thousands of caverns, power stations and other underground structures constructed in areas with frequent large magnitude earthquakes. These provide an enormous body of precedence relating to seismically induced damage to underground structures. This has been captured in a number of general [Power et al. 1998] and radwaste-related reviews [Bäckblom &, Munier 2002].

The key message from all these studies is that while the impact on a particular structure depends on the local geological conditions and the type of rock support employed, the damage seen underground is relatively minor and much less than that recorded at the ground surface for the same events.

A review of 192 reports of damage from 85 earthquakes compiled by Sharm & Judd [1991] shows the general decrease in damage with depth, see Figure 1. In particular, reports of 'heavy damage' are confined to structures less than 300 m deep.

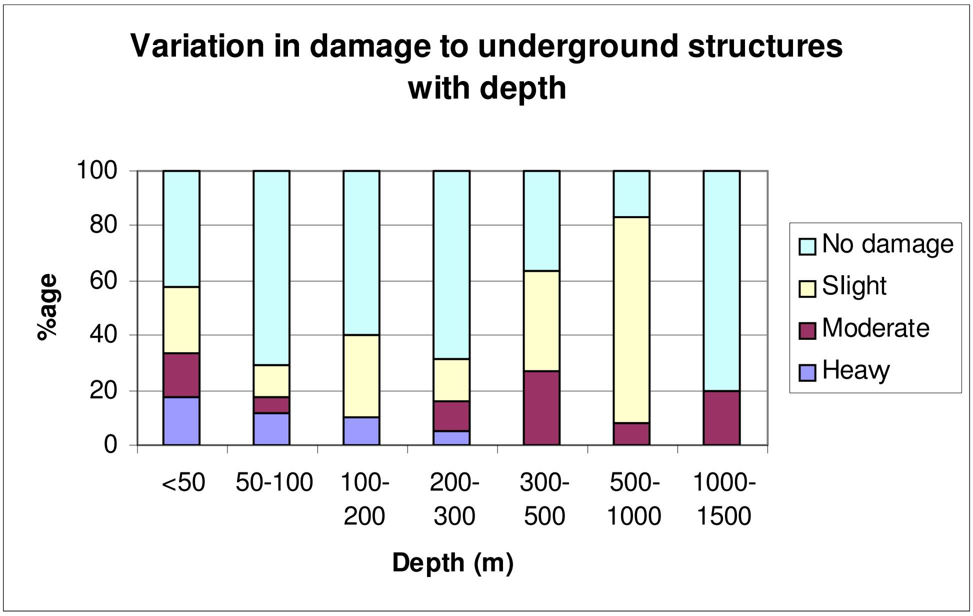

Figure 1. Variation of damage to underground structures as a function of depth. Based on data compiled by Sharma & Judd [1991]. 192 reports from 85 earthquakes world wide are included.

The same effect can be seen in individual earthquakes. A very good example of this is the 28 July 1976 Tang-Shan magnitude M=7.8 earthquake in China. It occurred close to the industrial city of Tan-Shan with a population of ~1 million. At the surface, 78% of industrial and 93% of domestic buildings were destroyed. The official death toll was 240,000-250,000 but estimates as high as 500,000 have been made [Wang Jing-Ming 1985]. In deep coal mines nearby, 30,000 miners were trapped for a short time but there were no fatalities.

There was only slight damage to the mine infrastructure and no serious damage to rock-stability in the mines was reported. Interviews with miners and examination of the damage showed that the intensity of the earthquake decreased rapidly with depth, so that at 600 m deep the intensity was only VII compared to XI at the surface, see Figure 2.

Relevance*:* This type of precedence is relevant to all types of disposal concepts and is useful in that it demonstrates one of the advantages of repositories constructed at depth compared to those constructed on or near the ground surface. It provides useful analogues both at a technical level and for communication with the public.

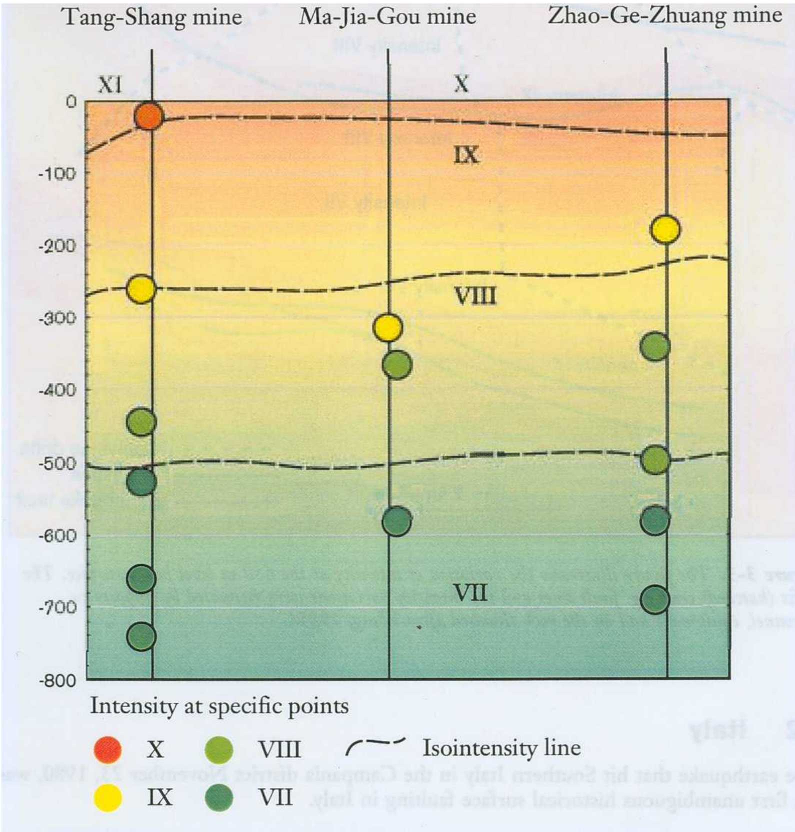

Figure 2: Decrease in earthquake intensity as a function of depth recorded in coal mines during the 28 July 1976 Tan-Shan earthquake, China. Taken from [Bäckblom & Munier 2002].

Example intensities at VII and XI:

VII Everybody runs outdoors, damage negligible in buildings of good design and construction; slight to moderate in well built ordinary structures; considerable in poorly built or badly designed structures; some chimneys broken. Noticed by persons driving cars.

XI Few, if any (masonry) structures remain standing, Bridges destroyed. Broad fissures in ground. Underground pipelines completely out of service.

Position(s) in the matrix tables:
No comments here

Limitations: In detail the seismic risk and attenuation with depth will differ with location so this does not overrule site specific data.

Quantitative information*:* Quantitative data is available for specific localities such as Tan-Shan noted above. Trends in intensity are likely to be general even if specific quantitative data is likely to be site specific.

Uncertainties*:* Site specific seismic attributes will affect the response of each site to seismic shaking.

Time-scale: The analogue is most relevant in the human (0 – 100 years) and historical (100 – 1000 years); time-scales.

PA/safety case applications*:* Not known.

Communication applications*:* Not known.

References:

Bäckblom G., Munier R. 2002. Effects of earthquakes on the deep repository for spent fuel in Sweden Based on case studies and preliminary model results. SKB Technical Report TR-02-24.

Power M.S., Rosidi D., Kaneshiro J.Y. 1998. Seismic vulnerability of tunnels and underground structures revisited. Proceedings North American Tunnelling '98, Newport Beach, California. Balkema, Rotterdam, 243-250.

Sharma S., Judd W.R. 1991. Underground opening damage from earthquakes. Engineering Geology, 30, 263-276.

Wang Jing-Ming 1985. The distribution of earthquake damage to underground facilities during the 1976 Tang-Shan earthquake. Earthquake Spectra, 1(4), 741-757.

Added value comments*:* The analogue has the potential to be used at any deep repository site in order to help allay concerns raised by the public that the waste will be vulnerable to earthquake damage.

Potential follow-up work*:* None is suggested.

Keywords*:* Earthquakes, shaking, depth attenuation.

Reviewers and dates*:* Les Knight, Nirex (October 2004).