Extension Ideas - Quake shake - will my home collapse?

When an earthquake strikes – investigate why some buildings survive and others do not

From Thomas McGuire, Arizona, USA
Student groups could have a contest to design tremor resistant structures followed by a 'quake-off' to discover 'the last man (structure) standing'.

From a colleague in Japan
Watch this video for an easy way to understand liquefaction. It is in Japanese but just press the 'play' button.
http://ppd.jsf.or.jp/jikken/jikken/30/index.html

From John Lahr, Emeritus Seismologist, US Geological Survey, Central Region Geologic Hazards Team
Has an earthquake engineer reviewed the Quake Shake lesson? I'm a seismologist, not an engineer, so am not certain but:

1) I think the serious collapse of building in Mexico City in 1985 was due to resonance of building of a certain range of heights that were built on a thickness of sediments that resonated at the same period. Liquifaction may have also been a factor, but I've not heard about it. An engineer would know.

2) This exercise might imply that liquifaction is the main cause of building collapse. It's just one of many.

3) I'm not sure what the wood represents in the Earth. Perhaps a better foundation? Perhaps a thinner layer of sediments? What is the best analogy?

4) "these waves reach the surface and cause surface waves - undulations of the Earth's surface."

When P and S waves reach the surface, they shake the ground, but they are not called surface waves. Surface waves are a particular type of wave that can only travel along the surface of the Earth. There are two types, Love and Rayleigh.

From Paul Denton in response to John's comments above
I agree with most of John's comments.

The photo that you use shows buildings tipping over due to liquifaction in the Niigata, Japan earthquake, June 16, 1964. The Mexico City Earthquake did highlight the problem of building resonance causing collapse, the role of the sediments in this earthquake was to amplify and focus surface waves of a particular frequency, this frequency was close to the resonant frequency of many buildings with heights 6-15 stories. See the following website for more details - -
http://www.ngdc.noaa.gov/seg/hazard/slideset/3/3_slides.shtml

Another earthquake which caused damage by significant liquefaction was the Loma Prieta earthquake in California which caused liquefaction in the marina district
http://www.ngdc.noaa.gov/seg/hazard/slideset/13/13_slides.shtml

Unfortunately Surface waves have never been a formal part of the UK science curriculum and most GCSE (14-16) texts do not mention them at all. I have had a few teachers ask me "what causes surface waves?" This is a hard question to answer without resorting to mathematics. The simplest explanation that I have come across is by Peter Shearer in "Introduction to Seismology, Chapter 8". In this he describes Love Waves as being caused by constructive interference between high order SH surface multiples (SSS,SSSS,SSSSS etc). Rayleigh waves are more complicated involving interference between upgoing P and SV waves, downgoing P and SV waves (the complication being caused by the fact that each reflection causes conversions of P waves to SV waves and SV waves to P waves as well as straightforward reflections). It seems therefore not unreasonable to describe surface waves as being created by the interaction of P and S waves with the free surface. Larry Braile has some very good animations of P, S, Love and Rayleigh waves at
http://web.ics.purdue.edu/~braile/edumod/waves/WaveDemo.htm

From John Lahr, US Geological Survey, in response to Paul's comments
I guess what bothers me the most about the current wording of this exercise are the misconceptions that might arise.

I think that it should be emphasized that liquefaction is one of many potentially damaging consequences of an earthquake. Shaking alone can cause building failure. Additional factors include:
• Ground displacement due to Faulting
• Shaking induced ground displacement or weakening:
  Landslide
  Liquefaction
• Shaking and/or displacement induced effects on water bodies:
  Seiche
  Tsunami

• Secondary consequences
  Dam failure
  Fire
  Utility breaks and disruptions (gas, electric, transportation...)

Perhaps an introductory paragraph, something like this, would place liquefaction into the context of just one hazard associated with earthquakes.

"Earthquakes pose a serious hazard, especially to structures. Clearly, a building that is built across a fault will be damaged if that fault ruptures during an earthquake. However, most buildings are damaged due to the shaking which earthquakes produce. This shaking can both trigger landslides as well as cause some soils to lose their strength, called liquefaction. Shaking and ground displacement can also generate ocean waves, called tsunamis, and waves in smaller bodies of water, called seiches. This lesson will focus on liquefaction."

I don't think liquefaction can only be caused by surface waves, which seems to be the implication of the following bullets:
• "these waves reach the surface and cause surface waves - undulations of the Earth's surface."
• "the waves cause solid rocks to move, but when they hit waterlogged sand, the sand can lose cohesion and 'liquify' causing heavy masses (eg. buildings) to sink, fall over or collapse.
In a nearby earthquake, surface waves are not developed locally, but liquefaction can be still be generated by the P, P coda, S, and S coda waves.

Perhaps the first bullet was not meant to be limited to "surface waves" in the seismological sense, as opposed to "waves at the surface." Also, the waves may not have to "reach the surface" - if the earth-quake is shallow, they are generated at the surface.

Could it be reworded?:
• "these waves can cause the surface layers of the Earth to shake violently.
• "the waves cause solid rocks and dry soils to vibrate, but when they hit waterlogged sand, the sand can lose cohesion and 'liquify' causing heavy masses (eg. buildings) to sink, fall over or collapse.

I hope these suggestions are constructive.

From Professor James Jackson, University of Cambridge, UK
I have attached an extract about the liquefaction of the Ganges plain in the 1934 Bihar earthquake; this gives you a taste of what is to come - -

". . . . As the rocking ceased . . . water spouts, hundreds of them throwing up water and sand, were to be observed on the whole face of the country, the sand forming miniature volcanoes, whilst the water spouted out of the craters, some of the spouts were quite five feet high. In a few minutes - as far as the eye could see - was a vast expanse of sand and water, water and sand. The road spouted water and wide openings were to be seen across it ahead of me, and my car sank, while the water and sand bubbled and spat, and sucked, till my axles were covered. 'Abandon ship' was quickly obeyed, and my man and I stepped into knee deep water and sand and made for the shore."

From the Bihar-Nepal earthquake of 1934, Memoirs of the Geological Society, India, 73, 391 pp,1939 (p34).