British Geological Survey
NATURAL ENVIRONMENT RESEARCH COUNCIL

UK Geohazard Note

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Seismic hazard

Damage to a home in Folkestone, Kent, following an earthquake in May 2007. Image © NERC.

Why do earthquakes occur?

Earthquakes are a natural result of living on a dynamic planet. The greater part of the Earth's interior is made up of the semi-molten *mantle*, which slowly turns over in vast convection currents caused by interior heating. The thin, mostly rigid crust of the planet on which we live is carried about on these currents, and the resulting stresses cause rocks to break along lines of weakness known as *faults*. Rocks bend, break and snap back releasing large amounts of energy in the form of waves that spread outward from the fault break. Each breaking event is what we call an earthquake.

The majority of earthquakes, and almost all of the great ones, occur at the edges of the *tectonic plates* that the Earth's crust has been broken into, especially where these plates are colliding head-on, as in the case of northern India, the Pacific coast of South America, and elsewhere. However, the stresses exerted at the edges of a plate still affect the plate's interior, so earthquakes can occur anywhere, including the UK. These *intraplate earthquakes*, as they are called, are generally less frequent and smaller than those at plate boundaries, although earthquakes greater than magnitude 8 have occurred in these settings.

The threat from earthquakes

There is a common misperception that earthquakes mostly involve the opening up of great chasms, or that California could sink into the sea. In reality, any apparent 'chasms' (as seen in some photos from 1906 San Francisco and 1964 Alaska) are a secondary effect caused by the slipping of unstable slopes. If a building is built directly across a fault, and that fault breaks in an earthquake, then of course the building can be torn apart. This can, and indeed has, happened in the past (notably to a dam in Taiwan in 1999) but is uncommon.

The main problem is the shockwaves that radiate out from the breaking part of the fault. Buildings are

Overview

- The main hazard posed by earthquakes is strong ground shaking; this causes buildings to collapse, which causes injury and death to the occupants, as well as economic loss.
- The main defence against earthquakes is to build safer buildings. Seismologists routinely advise engineers on the level of shaking expected in any part of the world, so that appropriate countermeasures can be planned.
- The UK is in a low to moderate hazard region. Specific safety measures are not needed for most buildings, but are required for high-consequence structures such as dams and nuclear facilities.

generally built to withstand a vertical force — earthquake shaking applies a sideways force that houses may be unable to resist. Collapsing buildings then fall in on their occupants, crushing them to death or trapping them under debris.

The other main causes of death and destruction in earthquakes are two secondary effects. Fires are caused due to overturned cooking stoves or broken gas mains and can easily rage out of control, as in San Francisco in 1906 and Tokyo in 1923. Tsunamis are giant waves caused when an earthquake flips up part of the sea bed, displacing a vast amount of water, as in Sumatra in 2004 and Japan in 2011. In the latter case, probably 99% of deaths resulted from the tsunami.

Seismic hazard

The first question to be tackled for any region is 'What earthquakes have affected here in the past?' The earthquake catalogue, which ideally should be extended as far back in history as possible, gives a good indication of what is to be expected in the future. The second question is 'Why did they occur?' Here the seismologist and geologist work together, trying to identify which faults are dangerous and which are not. Putting these two strands together, one arrives at a model of the seismicity of a region that describes both where earthquakes are expected to occur, and how often (but not exactly when).

The third question concerns the effects an earthquake will have. If a magnitude 6 earthquake happens 20 km away (for example), how strong is the shaking likely to be? Ground motion is stronger from larger earthquakes, and weaker with increasing distance from the fault, but the rate of decay may be different in some parts of the world from others.

Suppose an engineer is building a dam to last 50 years. One cannot know exactly what earthquakes will occur in that time, but using the model, one can make millions of forward projections of what could happen, consistent with all we know about the geology and seismicity of the region. And from that, it is simple to identify what sort of shaking is very likely to be observed in a 50 year period, what level

UK Examples

Because the UK has a rich written history, we can track earthquakes in the British Isles back to the end of the first millennium. By plotting where historical earthquakes were felt at different strengths of shaking (for instance, where there was damage, where the shock was felt by many, where it was only felt by few — this is referred to as intensity) and comparing the results with modern quakes, we can estimate magnitudes and epicentres for earthquakes that happened hundreds of years before seismometers were invented.

Damage from British earthquakes is typically light. The major observed effects are the fall of parts of old chimney stacks in poor repair; bricks and chimney pots come crashing down onto roofs, causing secondary damage. Cracks to interior plaster and fall of plaster also occurs. Complete collapse of buildings is almost unknown, and injury and death is very rare. The most damaging earthquake in the last 400 years occurred in 1884, near Colchester. This earthquake was not particularly large, but the fault broke at shallow depth, so the villages nearby received a more concentrated kick from the shockwaves.

But even though larger earthquakes are rare in the UK, given the consequences of an unexpected quake hitting a nuclear power plant or other critical structure, much work has been put into seismic hazard research in the UK. The largest recorded British earthquake was on 7 June 1931 (6.1 ML–local magnitude), which was fortunately located offshore in the North Sea. Minor damage occurred on the east coast of England, with one death in Hull.

Recent British earthquakes included the Folkestone earthquake of 28 April 2007 (4.3 ML) which caused considerable damage to older buildings in one part of the town. Emergency measures were taken — the first time these were ever put into place for a British earthquake. A much larger earthquake (5.2 ML) occurred the following year in Lincolnshire, but this caused little damage on account of its depth (18 km compared to 5 km for Folkestone).

Damage in the city of L'Aquila, Italy, following the earthquake of 2009. Image © NERC.

is less likely, and what is possible but very unlikely. The engineer can then design accordingly.

Fault breaks at the surface have never been observed in any British earthquake, and are so unlikely that the risk of it can be discounted for all but the most sensitive structures, where very low probability events are taken into consideration.

Scientific detail

Predicting earthquakes

It used to be thought, 50 or 60 years ago, that earthquake prediction would soon provide regular reliable warnings of impending earthquakes. In the 2010s we are no closer to realising that goal, which many seismologists now believe is impossible. Earthquakes are simply too chaotic to ever be predicted reliably. It used to be hoped that some signal would be discovered such that detecting the signal always meant an earthquake would follow, and not detecting it always meant no earthquake was on its way. We are now fairly confident that no such signal exists, which means that at the very best, earthquake prediction can only be occasionally successful.

Even if earthquake prediction could be perfected, it would save lives, but do nothing about the economic losses caused by earthquakes.

Earthquake resistance

The best defence against earthquakes is to construct buildings that can withstand them. Reinforcing structures against sideways forces, or insulating them from ground movement, are just two of the techniques earthquake engineers have developed. Critical facilities like major dams need special measures. But these increase building costs, so it is uneconomic to protect every building to the maximum when this might not be needed. A balance needs to be struck. This is where the seismologist steps in to assess the earthquake hazard at any particular location.

BGS activity in seismic hazard

BGS has been providing information on seismicity worldwide and on seismic hazard since the 1970s, and has been active in developing new methods for use in seismic hazard analysis. In addition to conducting site-specific studies of seismic hazard for a wide range of clients, BGS staff have also been involved in large-scale international projects, collaborating with, amongst others, INGV (Instituto Nazionale di Geofisica e Vulcanologia, Italy), ETHZ (Eidgenössische Technische Hochschule Zurich, Switzerland), GFZ (German Research Centre for Geosciences), NORSAR (Norwegian Seismic Array), University of Vienna, University of Weimar, University College London, Imperial College London, the University of Edinburgh, and major engineering companies such as Halcrow and Arup.

Earthquake monitoring in the UK

The BGS seismic monitoring network in the UK started in 1970, and has recently been upgraded to over 35 broadband instruments up and down the country. Funding is supplied by a customer group of interested parties, including national and local government, the nuclear industry, coal, water, and others. Immediate alerts are sent to members of the customer group whenever an earthquake strong enough to be felt in the UK occurs, or in the case of major earthquakes worldwide. Press releases are issued after events large enough to be of public concern. Information on recent earthquakes is always available from the BGS Seismology website (see below). As part of the international seismological community, BGS passes data on world earthquakes from its stations to the international monitoring agencies, such as the US Geological Survey, the European/Mediterranean Seismological Centre, and the International Seismological Centre.

Seismologists at work. The BGS Edinburgh office at Murchison House is the headquarters for earthquake monitoring in the UK, where data recorded by the UK network for both local and world earthquakes are collected and analysed. Image © NERC.

Further information

BGS Seismology Web pages: http://earthquakes.bgs.ac.uk
Email – enquiries@bgs.ac.uk
Telephone – 0115 9363143