

Engineers designing structures in seismically active areas know they need to make buildings safe from earthquake damage. But how safe is safe enough? asks **Roger Musson**.

Assessing earthquake risk

Many years ago most people thought that one day the threat to society from earthquakes would be solved, or at least mitigated, through earthquake prediction. If we knew in advance where and when a major earthquake was about to strike, appropriate defence measures could be taken to ensure that loss of life was kept to a minimum.

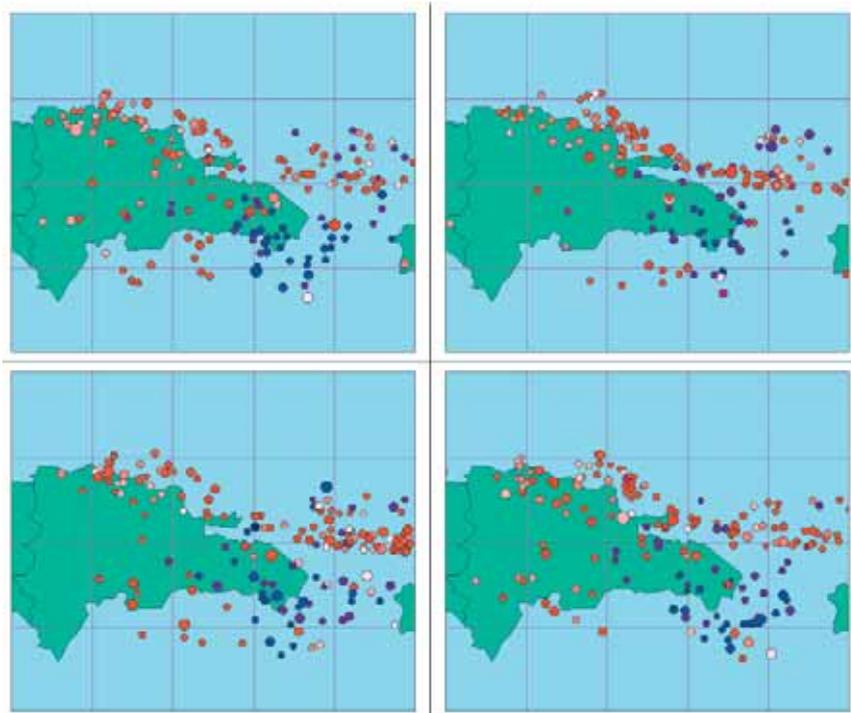
Despite enormous efforts, no consistent way of predicting earthquakes has ever been found, and there is a growing belief that earthquakes may be inherently unpredictable, at least with regard to the sort of prediction that could be exploited for civil defence. So another way has had to be found to tackle the earthquake threat.

At present it seems that the best way to defend against earthquakes is through engineering solutions. If buildings are designed so that they do not collapse in an earthquake, the occupants will not suffer serious injury. The need to know when an earthquake will happen is removed. Whenever the earthquake occurs, people will be safe because their built environment is earthquake-resistant. The success of this approach can be seen in cases like the Kobe earthquake of 1995. Although 5480 people lost their lives in this earthquake, it was conspicuous, when the damage was examined afterwards, that recent buildings with good design suffered only minor damage, while older buildings (many in poor condition) collapsed.

However, much as it would be good to construct all buildings to resist earthquakes, in practice, antiseismic design features are expensive. The

engineer has to trade safety off against cost. As a result, the question 'how safe is safe enough' becomes rather important. Too few safety features, and the building may collapse; too many and the building

becomes wastefully expensive. The engineer therefore needs a good idea of exactly what the hazard from earthquakes is. Often the first stage is simply to determine whether a site is in a seismically active area or not. For this, simple maps of earthquakes or generalised hazard maps will suffice. Determining the hazard level more precisely for any place is a task for the



Fifty years of seismicity in the Dominican Republic: one map is historical data and the other three are simulations from a model. Can you guess which is which? (Size of symbol shows magnitude and colour shows depth: darker events are deeper).

seismologist. Without a crystal ball we cannot tell exactly what earthquakes are going to hit a building in the course of its economic life, but we can certainly assess the most likely outcomes, and even determine the odds. Risk cannot be eliminated altogether, but we can define an acceptable level of risk. If the engineer decides that it is enough to be 99% sure that the strength of shaking the building is designed to withstand will not be exceeded in the building's lifetime, then the seismologist can determine the strength of shaking that has a 99% probability of occurring. The engineer then takes this as his design value. This process is known as a probabilistic seismic hazard assessment, or PSHA.

The way in which PSHA is practised in the BGS is easy to explain. The seismologist constructs a numerical model that describes all the earthquake sources in a region, together with their characteristic behaviour. Now imagine that we are concerned with a building that is expected to last for 50 years. The model can be used to run projections of possible seismicity for the next 50 years.

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No one can say exactly what the next 50 years will hold, but possible projections compatible with past seismicity can easily be generated. If one generates, say, 10 000 such projections and notes the strongest shaking at the location of the building in each of them, then one can easily find the value that is exceeded 50% of the time, 10% of the time, 1% of the time, and so on. This stochastic simulation approach is very powerful, and also easy to understand, since the probabilities are all derived from observation of all the possible future outcomes. The results are the same as those obtained by analytical methods, but easier to check.

The hard part is setting up the numerical model in the first place. Just looking at an earthquake catalogue does not necessarily tell you all you need to know about the entire seismic process; ‘smoothing’ the seismicity, as is sometimes done, may blur over important local variations in hazard that are geologically explicable.

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The analyst's task is to interpret the historical seismicity in the light of an understanding of the tectonic processes that are operating in the region. Often, this understanding can only be partial, and it becomes important to take uncertainty into account, for instance by using different interpretations as weighted alternatives. One of the fascinations of seismic hazard analysis is the way in which so many different types of information are distilled together to make the final model. The earthquake catalogue draws not only upon the skills of the seismologist but often also the historian and even the archaeologist.

Contributions from the geologist, the geophysicist and the geodesist are combined in piecing together the pattern of seismogenesis. Seismic hazard really benefits from a truly multidisciplinary approach, in which, by amalgamating expertise across the earth sciences, we can more effectively understand and quantify the hazard from earthquakes worldwide. The more we can do this, the more we can do effectively and efficiently to protect our societies from earthquakes.

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Three photographs of damage from the Kobe earthquake of 17 January 1995. In these pictures you can see clearly that the amount of damage suffered by buildings in the city was variable. Some older buildings collapsed completely or partially, while their neighbours, newer and better designed, were undamaged.

Photographs by Robin Spence