

Geological events can be hazardous to life and the built environment, for example earthquakes, volcanic eruptions, landslides and tsunamis. Earthquakes are concentrated along plate tectonic boundaries; hazards include building collapse, ground liquefaction, fires and landslides. Volcanic eruptions are also concentrated on plate boundaries; hazards include lava flows, ash fall, pyroclastic flows and lahars (volcanic mudflows). Landslide hazards can be initiated by earthquakes, volcanic eruptions and slope failure. Tsunami hazards can be generated by submarine earthquakes, volcanic island collapse, landslides into the sea or meteorite impacts in the sea.

**The level of risk of a hazard** is associated with threat to life and damage to property and relates to:

**Population density** – the higher the population density, the more likely the greater number of fatalities. LEDC's with high population densities are most at risk

**Technology** – the degree of technology incorporated into building design. Most MEDC's in hazard-prone regions have invested in aseismic building design, early warning systems and rapid response emergency services. In addition, land use planning has resulted in cities leaving the most susceptible areas to open space, parks and golf courses, whilst emergency services, hospitals and schools are located in the least susceptible areas. Areas of intermediate risk will be used for housing, public buildings and retail parks/shopping centres

**Development** – LEDC's have little or nothing to invest in hazard management because of more pressing concerns such as educating children, providing shelter/housing and health care often for millions of individuals. Communicating information regarding hazards and risk is also a problem, with many LEDC's having limited infrastructure to disseminate the information (a lack of PC's, broadband, literacy and political will).

The level of accuracy of hazard prediction is limited. The methods of reducing risk include:

## **Building design and regulation:**

- Minimum standards for reinforced concrete strictly enforced
- Plexiglas/safety glass to replace conventional glass in skyscrapers
- Retrofitting of foundations with rubber dampers as in Oakland City Hall in California
- Installing smart valves to turn off oil/gas supplies when an earthquake of magnitude 5 or greater occurs as in Japan
- Use of bolts to pin floors to walls to reduce the likelihood of 'pancaking' in multi-storey buildings
- Fastening major appliances such as fridges, wardrobes, bookcases and huge TV screens to walls/ floors to stop movement during an earthquake
- Buildings on stilts in areas prone to tsunamis so water can flow underneath
- Planting of mangroves in coastal areas prone to tsunamis to absorb the force of the waves
- De-watering of soil to help level up buildings that have suffered uneven subsidence during liquefaction in an earthquake
- Building deep foundations into solid bedrock for all new builds in earthquake-prone areas
- Constructing new builds with lower centres of gravity such as the Trans America Pyramid in San Francisco and the Beehive Building in New Zealand
- Using computer-controlled weights on the top of skyscrapers to counter any swaying caused by a seismic event
- Constructing multi-storey buildings which allow floors to slide horizontally using a rack and pinion device and teflon (non-stick) coated materials on the base/top of floors in contact with each other

- Investing in emergency services and rescue equipment including bulldozers, JCBs, cranes, fire engines, heat-seeking equipment, doctors, paramedics, hospitals and sniffer dogs
- Avoiding building on reclaimed land from the sea, marshes, old lake beds, river floodplains which are prone to liquefaction during an earthquake
- Identifying weak points in the infrastructure such as tunnels, bridges, flyovers and freeways and reinforcing them so that they are earthquake resistant
- Implementing building restrictions in areas prone to volcanic eruptions – for example, Mount Teide on Tenerife has a national park surrounding it which has blanket restrictions on any new developments.

## Prediction of Earth hazards:

**Hazard interval patterns (seismic gaps):** This can be seismic gaps in time or space. A detailed record of previous seismic events over time can be used to work out an average recurrence interval for a seismic event over a particular magnitude. Seismic events that have occurred along a particular fault line over time can also be mapped. Areas not having experienced seismic events are those most likely at risk when the next event occurs. Istanbul on the North Anatolian Fault is the location where the next major seismic event is predicted as all other parts of the fault have moved, releasing stress build up over the past 200 years.

**Ground deformation (tiltmeters):** These instruments measure minute changes in the angle of the Earth's surface. A pattern where the ground is increasing in angle or bulging over a period of time may indicate the movement of magma towards the surface. Eventually, the ground fails and there is a major earthquake followed by a volcanic eruption, as was the case with Mount St. Helens in Washington State in May 1980.

**Groundwater changes:** This involves the monitoring of water levels in boreholes and wells along with the water chemistry and temperature. Falling water levels and increases in dissolved radon gas sometimes occur before a major seismic event. Increase in temperature and dissolved sulphur dioxide and carbon dioxide levels may indicate magma is moving towards the surface which may lead to a volcanic eruption at some point in the future.

**Gas emissions:** Radon gas levels have been shown to increase in groundwater prior to a major seismic event as in Kobe, Japan in 1995. Sulphur dioxide and carbon dioxide emissions increase rapidly 24 to 48 hours prior to a volcanic eruption and can be monitored by correlation spectrometers (COSPEC) around active volcanoes.

## Warning schemes and evacuation:

Countries prone to earthquakes have regular safety drills, rather like fire drills in the UK. Schools in Japan teach children to 'duck and cover' in the likelihood of a seismic event. In California, USA, all households are provided with the publication '7 steps to earthquake safety' which gives advice on identifying hazards in the home and building a disaster survival kit that includes blankets, water, dried food, a torch, a mobile phone and a radio. Japan, which is prone to tsunamis, has clearly marked routes to enable the safe evacuation of large numbers of people in the danger zone. Tsunami warning systems are now in place in the Pacific and Indian Oceans which pick up the presence of tsunami waves via DART buoys (Deep-ocean Assessment and Reporting of Tsunamis) so that warnings can be issued quickly for people to move away from the coast.