BRANZ

ISSUE 558

BULLETIN

EARTHQUAKE TERMINOLOGY

April 2013

- Following the Canterbury earthquakes of 2010/2011, many articles and reports appeared describing the events and the impact they had on buildings.
- A number of specialised terms are used, some of which may be unfamiliar to many designers and builders.
- This bulletin explains in plain English some key words and phrases relating to earthquakes and, in particular, their action on buildings.

1.0 INTRODUCTION

1.0.1 The Canterbury earthquakes of 2010/2011 resulted in the deaths of 185 people and damage to tens of thousands of buildings.

1.0.2 The events led to a number of investigations taking place, most notably the Canterbury Earthquakes Royal Commission of inquiry, which completed its work in November 2012. Many articles and reports about the earthquakes, including the reports of the Royal Commission, have been published.

1.0.3 Documents that include explanations of the action of earthquakes on buildings often contain words and phrases that are not in common use outside of this specialised area. However, it may be useful for designers and builders from the industry as a whole to have a basic understanding of some of this terminology.

1.0.4 This bulletin explains in plain English some of the key words and phrases used in documents about earthquakes and designing and building to cope with earthquakes.

2.0 EARTHQUAKE TERMINOLOGY

AXIAL LOAD

A force acting along the long axis of a member or vertically in a wall.

BASE ISOLATION

A means of limiting the seismic forces on a building by supporting it on devices that allow relative movement to occur between the building and its foundation. A good example of base isolation can be viewed at Te Papa museum in Wellington, where 150 rubber and lead shock absorbers under the building let the building move up to half a metre in any direction during a big earthquake.

Base isolator, Wellington Hospital.

BASE SHEAR

The horizontal force at the base of a structure due to inertial forces acting during earthquake ground movement.

BENDING MOMENT

A bending moment occurs in a structural element (such as a beam) when forces are applied at right angles to the element so that it bends. Bending moments produce tension on one side of the element and compression on the other side.

The bending moment at any point along a beam can be calculated from all the external forces acting on the beam. The calculation is important because it can show where the greatest amount of bending will take place. If a beam has a uniformly distributed load, the bending will occur in the middle of the span.

BUILDING CLASSIFICATION

The standard AS/NZS 1170.0.2002 *Structural design actions – Part 0: General principles* classifies buildings in levels of importance (IL) from 1 to 5, where 1 is the lowest level of importance. Most multi-storey buildings are included in IL 2, IL 3 includes buildings likely to contain large numbers of people and IL 4 includes hospitals and other buildings that must be operational straight after a big earthquake. The IL of a building dictates the intensity of earthquake loading that it must be able to cope with.

CERA

Canterbury Earthquake Recovery Authority.

CONE PENETROMETER TEST (CPT)

A widely used test that measures the properties of soil beneath the surface in a particular location. A cone is pushed at a controlled rate into the ground, sometimes for many metres deep, and measurements are taken. Soil samples are not usually taken. CPT testing can help determine the suitability of the soil for a particular type of building and whether ground improvement is required.

CONFINEMENT REINFORCEMENT

This is used to make reinforced concrete beams and columns stronger and more ductile so they can perform better in an earthquake. Confinement reinforcement (usually in the form of spirals or stirrups) is designed so that it 'confines' the core concrete inside it, giving it better compressive strength and more strain capability.

DIAPHRAGM

A flat (usually horizontal) structural element or system that transmits horizontal forces (typically from wind or earthquakes) to and from shear walls or frames. Floors often act as diaphragms.

DOUBLE TEE

A precast/prestressed concrete unit commonly used in floors or roofs.

DRIVEN PILE

A driven pile can be made of timber, steel or precast concrete and is typically hammered into the ground to form foundations. They are often used in soft ground conditions. It is not unusual for driven piles to reach 10–15 metres depth. "…driven piles have significant advantages over other pile types for reducing settlements in earthquake-resistant design…" (Royal Commission).

DUCTILE WALL

Like most reinforced concrete building elements, a reinforced concrete wall generally performs better in an earthquake if it is designed to be ductile. The ductility of a wall depends on, among other things, its proportions, the design of its reinforcement and how it is connected to other building elements.

DUCTILITY

Originally used in metallurgy, ductility is a measure of how easily a solid material (such as a metal) deforms under stress without breaking. In earthquake engineering terms, ductile systems allow structures to deform inelastically and so absorb earthquake energy without collapsing.

EARTHQUAKE-PRONE

Although people often speak of "earthquake-prone" buildings to simply mean ones that are at greater risk of damage in an earthquake, there is a specific definition of this term in the Building Act 2004 (section 122). A building is earthquake prone if it:

a) will have its ultimate capacity exceeded in a moderate earthquake (as defined in the regulations); and

b) would be likely to collapse causing—

  i) injury or death to persons in the building or to persons on any other property; or

  ii) damage to any other property.

The definition doesn't apply to residential buildings unless they are two or more storeys and contain three or more household units.

In practical terms, a building is earthquake-prone if, when assessed against current standards for new buildings, it is considered that it would not sustain more than 33% of the minimum design actions for the **ultimate limit state**.

EARTHQUAKE-RISK BUILDING

A building is an earthquake-risk building if, when assessed against current standards for new buildings, it would sustain only between 33% and 66% of the minimum design actions for the **ultimate limit state.**

In terms of its likely performance in an earthquake, a building assessed at 33% of new building strength has about 20 times the risk of failure compared with the equivalent new building, and a building at 66% has about five times the risk.

ECCENTRICALLY BRACED FRAME

Building framing is braced so that it copes with wind and earthquake forces. An eccentrically braced frame is one with diagonal bracing that is not concentric. The active links between the eccentric braces give the frame a level of stiffness and ductility that allows it to better cope with big lateral loads induced by earthquakes – the framing can absorb a lot of energy without breaking. This sort of framing is very commonly used in areas of high earthquake risk.

Eccentrically braced frame. (Source: Ruamoko Solutions.)

GEOTECHNICAL INVESTIGATION

An investigation by a specialist engineer or geologist into the physical properties of the rocks and soils at a particular location. This work is often necessary to determine what foundations or earthworks are required under a planned building.

GROUND IMPROVEMENT

Techniques to improve the strength and stability of soil so it better supports a building. Used particularly on soft soils or soils subject to liquefaction, ground improvement techniques include:

- dropping a heavy weight repeatedly onto ground to make it denser – before Te Papa museum was built, 30 tonne weights were dropped onto the ground 50,000 times
- excavating the top few metres of soil then recompacting on site – cement may be added to the mix for improved performance
- inserting deep columns into the ground that will provide added support under a building
- inserting deep columns around a site to create a supporting curtain wall.

HOLLOW-CORE SLAB

Precast, prestressed concrete slabs that are often used in floor construction in multi-storey buildings. The slabs have tubular voids running through the full length, making them much lighter than solid slabs of equal thickness.

IEP

Initial evaluation process, usually carried out by a local building control authority to determine whether a building is likely to be earthquake-prone or an earthquake risk. It is a very simple filter that needs to be verified by a more detailed assessment usually by the building owner with the help of a structural engineer.

INCLINED PILE

A pile that goes into the ground on an angle rather than vertically so as to better resist horizontal forces.

IN-PLANE AND OUT-OF-PLANE FORCES

In-plane forces act in the same plane as the face of the wall, while out-of-plane forces act at right angles to the face of the wall.

INTENSITY

A measure of the effects of an earthquake on people and buildings at a particular location. The intensity at a particular site depends on the strength (**magnitude**) of a quake, how far the site is from the epicentre of the earthquake and the geology under the site.

Intensity is measured with the 12 point Modified Mercalli Intensity (MMI) scale.

A classification is made by accumulating the results of many observations on the ground. The scale is linear, not logarithmic, which means that going up the scale is a gradual process – 1 is not felt by most people; 12 results in total destruction. The September 2010 and February 2011 Canterbury earthquakes (magnitude 7.1 and 6.3 respectively) are both classed as 9 on the MMI scale. At this level, there is panic, partial collapse of buildings and buildings thrown off their foundations.

Intensity is different from **magnitude**.

INTER-STOREY DRIFT

Drift is a sideways movement of a building, and inter-storey drift is the difference in sideways movement between two adjacent storeys. The measurement is usually expressed as a percentage of the storey height. For example, if a storey is 3 m high, an inter-storey drift of 10% would mean that the floor of the upper storey moves by 300 mm compared to the floor below. A big inter-storey drift can lead to significant damage and even collapse of a building.

LATERAL LOADS

These are horizontal or sideways loads on the building. They are typically caused by the pressure of the wind on the exposed face of the building and suction on the opposite face. Lateral loads in earthquakes are caused by the inertial weight of the building when the ground accelerates beneath it.

Damage resulting from differential movement between the floor structure and the roof structure.

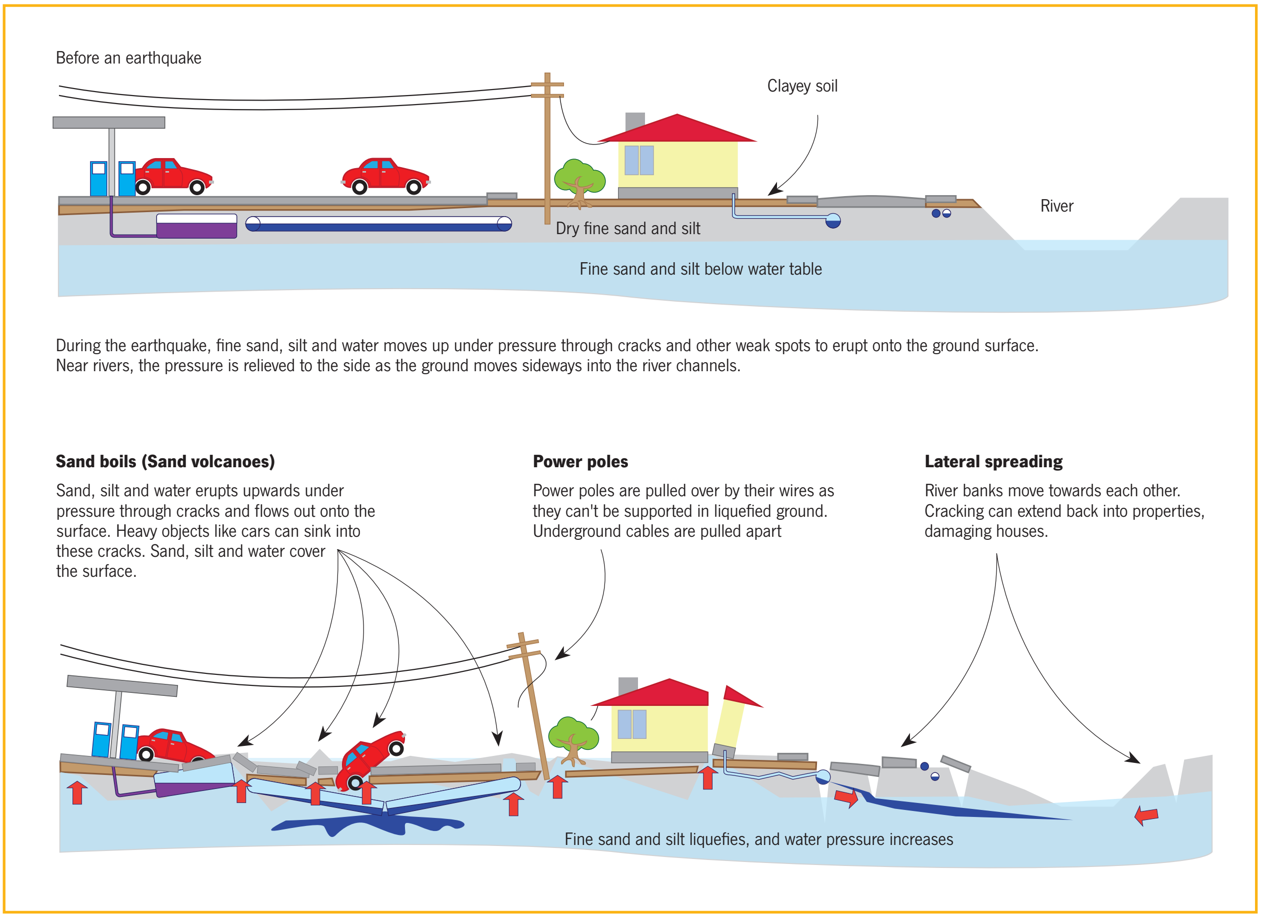
LIQUEFACTION

During liquefaction, soil suddenly loses strength. Not all soils liquefy. Those more likely to liquefy as the result of an earthquake are sands and silts that are made up of particles all of similar size below the water table, where all the space between the grains is filled with water.

Earthquake forces cause the sand and silt particles to rearrange themselves into a more compact volume, and the water is squeezed out of the reduced space between the particles. The loose granular soil starts to lose strength and behave like a dense fluid – hence the term ‘liquefaction’.

Road damage caused by liquefaction.

Liquefied soil can’t support the weight of whatever is above it – surface layers of soil or foundations of buildings. The liquefied soil under that weight is forced into any cracks and crevices it can find, including those in the soil above or the cracks between concrete slabs or paving. It flows out onto the surface and creates sand ‘volcanoes’ and streams of silt or sand.



Effects of liquefaction.

Liquefaction can also result in:

- settlement of the ground surface (and all or part of a building on the surface) due to the compaction of the underground soil – ground lowering may be enough to make the surface close to or below the water table, creating ponds
- floating of manholes and buried tanks and pipes that are mostly empty.

Settlement of the ground due to the compaction of the underground soil.

Where there are sloping ground surfaces, such as on riverbanks, surface soil layers can slide sideways on the liquefied soil. This is called lateral spreading and can occur even when the slope is very small. It typically results in long tears and rips in the ground surface. Lateral spreading can severely damage buildings if part of a building's foundations are pulled sideways more than another part.

Buried services such as sewer pipes can be damaged as they are twisted or moved by lateral spreading, uneven ground settlement or flotation. Liquefied soils that are not ejected onto the ground surface redensify and regain strength. In some cases, redensified soil may be stronger than before the earthquake.

LOAD

A force applied to a structure.

LOW-DAMAGE DESIGN

Design that means that, after a building displaces sideways in an earthquake, it will return to its original position. The non-structural elements are separated from the main structure so that they are not damaged by the deforming building.

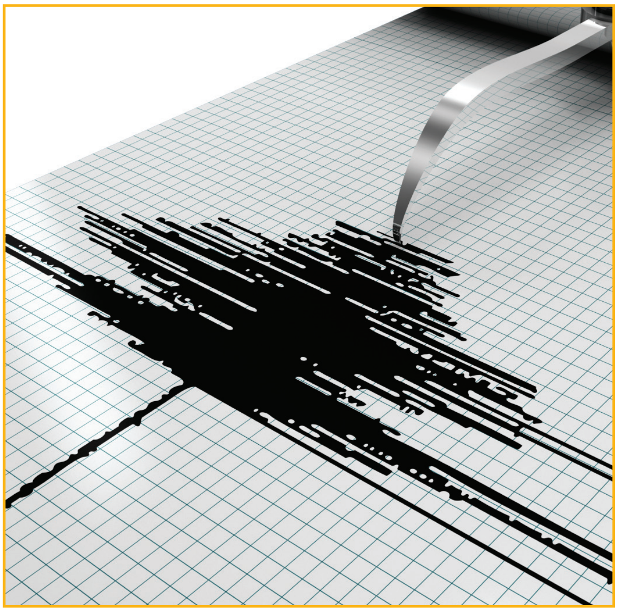
MAGNITUDE

A measure of the strength of an earthquake (the amount of energy it releases) at the point where it occurs. It is generally measured by the movement on a seismograph, corrected for the distance between the seismograph and the epicentre of the quake.

Magnitude is measured using the Richter scale. This is a logarithmic scale, which means that each unit of magnitude represents a very big increase in strength. For example:
- a magnitude 5 earthquake releases 30 times more energy than a magnitude 4 earthquake
- a magnitude 6.7 earthquake releases over 900 times the energy of a 4.7 earthquake.

Humans typically do not feel earthquakes below about magnitude 2.5.

Magnitude is not the same as **intensity**.



Seismograph.

MAXIMUM CONSIDERED EARTHQUAKE (MCE)

The MCE is generally taken as an earthquake that has a 2% probability in 50 years or a 2,500 year **return period**. The requirements of current New Zealand standards are such that new multi-storey buildings in New Zealand should have a small margin of safety against collapse in an MCE.

MOMENT-RESISTING FRAME

A structural frame typically consisting of reinforced concrete or steel beams and columns that are rigidly connected at their joints. Resistance against sideways forces of wind or earthquakes is by bending of the frame members.

NORMAL FORCE/NORMAL LOAD

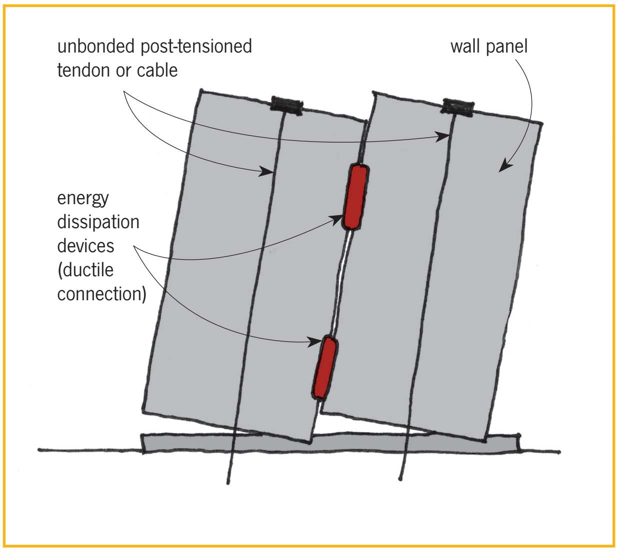
A force acting at 90° to an object – for example, your finger pressing straight down on a piece of wood. Compare this with **shear force.**

PLASTIC HINGE/POTENTIAL PLASTIC HINGE

The zone in a concrete beam or column or shear wall where reinforcement yields or stretches like plasticine under earthquake loading is called a plastic hinge zone or plastic hinge region. As the reinforcement yields, the energy of the earthquake is taken up. Potential plastic hinges in a building are identified during design, and structural elements outside these areas are designed to be stronger. Potential plastic hinges are therefore designed to allow some deformation during an earthquake. Similar zones may be identified in steel structures where the steel member yields to dissipate the earthquake energy.

PRECAST STRUCTURAL SEISMIC SYSTEMS (PRESSS)

PRESSS is a design and construction technique where unbonded, tensioned cables or bars are threaded through precast concrete walls, beams and columns, with jointed ductile connections. The cables and ductile joints let the building spring back to its original position after a large earthquake. (One writer said PRESSS is like a child's wooden doll with jointed limbs that are held together with elastic cord but are still moveable.)



Jointed rocking wall systems illustrating PRESSS. (Source: Buchanan report.)

The 5-storey Southern Cross Hospital endoscopy building in Christchurch was built with PRESSS technology. This building came through the February 2011 earthquake with relatively little damage and could be reoccupied immediately. The Alan MacDiarmid Building at Victoria University, Wellington, also uses PRESSS technology.

Some areas of PRESSS design are covered in Appendix B of NZS 3101:2006 *Concrete structures standard*.

RETURN PERIOD

The average number of years between earthquakes of a certain magnitude on a particular fault or at a particular location. Earthquakes with longer return periods are generally assumed to be bigger and release larger amounts of energy.

SERVICEABILITY LIMIT STATE (SLS)

This refers to buildings that can still be used for their intended purpose after an earthquake of the **magnitude** that can be expected once or twice during the life of the building. If a building remains standing and is still structurally sound, but cannot be used for its intended purpose, then the serviceability limit state has been exceeded. See also **ultimate limit state.**

SHEAR FORCE

A force acting in a direction parallel to the face of the material or to a planar cross-section of a body. See also **normal force.**

SHEAR WALL

A structural wall, commonly of reinforced concrete or timber, that often starts at the base of a building and runs for its full height. Shear walls transmit lateral earthquake forces down to the building foundation. A shear wall can also be described as a vertical **diaphragm**. They are typically stronger and stiffer than walls that do not serve this purpose.

STANDARD PENETRATION TEST (SPT)

A thick-walled tube of 50 mm outside diameter and 35 mm inside diameter is driven into the ground with a slide hammer, and the number of blows required to push it down over a particular depth is measured. The main purpose of this test is to provide an indication of the density of the soil.

STIC

Structural Timber Innovation Company – a company set up to develop the use of post-tensioned LVL (laminated veneer lumber) structures.

ULTIMATE LIMIT STATE (ULS)

This is concerned with the safety of people in buildings. To stay within its ultimate limit state, a building must still be standing after being subjected to the peak design load (the ULS load) for which it was designed.

For most multi-storey buildings, the ULS criteria are based on an earthquake with a **return period** of 500 years (10% probability in an assumed 50-year building life), but with buildings that provide essential services (hospitals, for example), the return period is increased, in some cases up to 2,500 years. See also **serviceability limit state.**

UNREINFORCED MASONRY

Concrete, stone or brick masonry that has no reinforcing steel included to make it work like reinforced concrete

Unreinforced masonry damage.

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ISSN 1170-8395