Appendix A

WHAT DO THOSE TECHNICAL TERMS MEAN?

MEASURES OF EARTHQUAKE MAGNITUDE AND INTENSITY

Earthquakes commonly are "measured" by use of two different scales – the *Richter magnitude scale* and the *modified Mercalli intensity scale*. As these two names indicate, one scale measures *magnitude* while the other indicates the *intensity* of the earthquake motion at specific places around the earthquake epicenter. Since both scales measure very different things, they cannot really be related to one another or compared. However, since both are used, the concerned individual should have a general understanding of both.

RICHTER MAGNITUDE

The Richter magnitude scale was developed by Charles F. Richter in 1935. It is defined as the logarithm to the base of 10 of the maximum trace amplitude in millimeters as recorded on a standard seismograph located 100 kilometers (or 62 miles) from the earthquake epicenter.

A Richter scale measurement is expressed in whole and decimal numbers and it can be used to identify the magnitude of an earthquake and estimate how much energy was released. In this context, it is important to remember that the Richter scale is logarithmic and, therefore, each unit of increase on the scale reflects a 10 times increase in amplitude. This represents approximately a 32-fold increase in energy released. Thus, an earthquake of Richter magnitude 8.3 would have an amplitude of 10,000 times that of an earthquake of Richter Magnitude 4.3 and would release approximately 1,050,000 times more energy.

As originally developed by Richter, this magnitude scale applied to Southern California shallow earthquakes located less than 375 miles from the recording instrument. Now, however, it is commonly used to compare earthquakes worldwide and at distances much farther from the recording instrument. Other magnitude scales have been developed that more accurately describe the variety of earthquakes that may be encountered, and the Richter magnitude scale is now recommended only for measuring earthquakes between about magnitudes 3 and 7. For the larger earthquakes that are of particular concern for seismic design, the *moment magnitude* (M_w) scale is now used by the U.S. Geological Survey and others. Moment magnitude is a combination of the *rigidity of the rock times the area of faulting times the amount of slippage*; this scale is based on the forces that work at the fault rupture to produce the earthquake rather than the recorded amplitude of seismic waves and is directly related to the energy released by the earthquake.

Moment magnitude, however, can be assigned only after considerable study of the geology and size of the fault rupture, while the Richter magnitude is almost immediately available after the shock. Thus, the Richter magnitude will continue to be a useful comparative index of earthquake size, even though, because of its limitations, it does not give an accurate measure of the earthquake effects in terms of damage.

Note that deep earthquakes more characteristic of the eastern United States are best compared by measuring their *P-waves*, which are not affected by the depth of the source. This measurement is referred to as *body-wave magnitude* (m_b).

MODIFIED MERCALLI INTENSITY SCALE

As noted, use of Richter magnitude gives little indication of earthquake intensity and building damage. The first scale created to do this was developed in the 1880s by the Italian *de Rossi* and the Swiss *Forel*. It was modified in 1902 by the Italian *Mercalli* and later further modified a number of times. A version of the Rossi-Forel scale generally is used in Europe while the modified Mercalli intensity (MMI) scale is used in the United States.

The following excerpt from Bruce A. Bolt's 1978 book, *Earthquakes: A Primer* (W. H. Freeman and Company, San Francisco, California), describes modified Mercalli intensity values (1956 version):

I. Not felt. Marginal and long period effects of large earthquakes.

II. Felt by persons at rest, on upper floors, or favorably placed.

III. Felt indoors. Hanging objects swing. Vibration like passing of light trucks. Duration estimated. May not be recognized as an earthquake.

IV. Hanging objects swing. Vibration like passing of heavy trucks or sensation of a jolt like a heavy ball striking the walls. Standing cars rock. Windows, dishes, doors rattle. Glasses clink. Crockery clashes. In the upper range of IV, wooden walls and frames creak.

V. Felt outdoors; directions estimated. Sleepers wakened. Liquids disturbed, some spilled. Small unstable objects displaced or upset. Doors swing, close, open. Shutters, pictures move. Pendulum clocks stop, start, change rate.

VI. Felt by all. Many frightened and run outdoors. Persons walk unsteadily. Windows, dishes, glassware broken. Knickknacks, books, etc., off shelves. Pictures off walls. Furniture overturned. Weak plaster, Masonry D cracked. Small bells ring (church and school), Trees, bushes shaken visibly or heard to rustle.

VII. Difficult to stand. Noticed by drivers. Hanging objects quiver. Furniture broken. Damage to Masonry D, including cracks. Weak chimneys broken at roof line. Fall of plaster, loose bricks, stones, tiles, cornices, also unbraced parapets, and architectural ornaments. Some cracks in Masonry C. Waves on ponds, water turbid with mud. Small slides and caving in along sand or gravel banks. Large bells ring. Concrete irrigation ditches damaged.

VIII. Steering of cars affected. Damage to masonry C; partial collapse. Some damage to Masonry B; none to Masonry A. Fall of stucco and some masonry walls. Twisting, fall of chimneys, factory stacks, monuments, towers, elevated tanks. Frame houses moved on foundations if not bolted down; loose panel walls thrown out. Decayed piling broken off. Branches broken from trees. Changes in flow or temperature of springs and wells. Cracks in wet ground and on steep slopes.

IX. General panic. Masonry D destroyed; Masonry C heavily damaged, sometimes with complete collapse; Masonry B seriously damaged. General damage to foundations. Frame structures, if not bolted down, shifted off foundations. Frames racked. Serious damage to reservoirs. Underground pipes broken. Conspicuous cracks in the ground. In alluviated areas, sand and mud ejected, earthquake fountains and sand craters.

X. Most masonry and frame buildings destroyed with their foundations. Some well-built wooden structures and bridges destroyed. Serous damage to dams, dikes, embankments.

Large landslides. Water thrown on banks of canals, rivers, lakes, etc. Sand and mud shifted horizontally on beaches and flat land. Rails bent slightly.

XI. Rails bent greatly. Underground pipelines completely out of service.

XII. Damage nearly total. Large rock masses displaced. Lines of sight and level distorted. Objects thrown in the air.

Note that the masonry definitions used are from C. F. Richter's 1958 book, *Elementary Seismology* (W. H. Freeman and Company, San Francisco, California), and are as follows: Masonry A – good workmanship, mortar, and design; reinforced, especially laterally; bound together by using steel, concrete etc; designed to resist lateral forces. Masonry B – good workmanship and mortar; reinforced but not designed in detail to resist lateral forces. Masonry C – Ordinary workmanship and mortar, no extreme weaknesses like failing to tie in at corners but not reinforced or designed against horizontal forces. Masonry D – weak materials such as adobe, poor mortar, low standards of workmanship; weak horizontally.

Unlike the Richter magnitude scale, whose values are set by instrumented readings, the Mercalli scale is subjective and values are set by observers based on interpretation of the above indicators. A problem with the Mercalli scale is that, due to its age, it has no references to modern structural types of reinforced concrete, steel, etc. On the other hand, since older buildings are most prone to damage, this limitation may not be too serious.

It should be noted that a given earthquake will have one Richter magnitude (once the various seismological stations agree) but will have a number of Mercalli intensities depending on the distance from the epicenter.

TERMINOLOGY

Acceleration – Rate of change of velocity with time.

Amplification – A relative increase in ground motion between one type of soil and another or an increase in building response as a result of resonance.

Amplitude – Maximum deviation from mean of the center line of a wave.

Architectural Components – Components such as exterior cladding, ceilings, partitions, and finishes.

Component (also Element) -- Part of an architectural, structural, electrical, or mechanical system.

Configuration – The size, shape, and geometrical proportions of a building.

Connection – A method by which different materials or components are joined to each other.

Damage – Any physical destruction caused by earthquakes.

Deflection – The state of being turned aside from a straight line, generally used in the horizontal sense; see also "Drift."

Design Earthquake – In the *Provisions*, the earthquake that produces ground motions at the site under consideration that has a 90 percent probability of not being exceeded in 50 years (or a 10 percent probability of being exceeded).

Design Ground Motion – See "Design Earthquake."

Diaphragm – A horizontal or nearly horizontal structural element designed to transmit lateral forces to the vertical elements of the seismic force resisting system.

Drift – Vertical deflection of a building or structure caused by lateral forces; see also "Story Drift."

Ductility – Property of some materials, such as steel, to distort when subjected to forces while still retaining considerable strength.

Earthquake – A sudden motion or vibration in the earth caused by the abrupt release of energy in the earth's lithosphere.

Effective Peak Acceleration and *Effective Peak Velocity-Related Acceleration* – Coefficients shown on maps in the *Provisions* for determining prescribed seismic forces.

Elastic – Capable of recovering size and shape after deformation.

Epicenter – A point on the earth's surface that is directly above the focus of an earthquake.

Exceedance Probability – The probability that a specified level of ground motion or specified social or economic consequences of earthquakes will be exceeded at a site or in a region during a specified exposure time.

Exposure – The potential economic loss to all or certain subsets of the built environment as a result of one or more earthquakes in an area; this term usually refers to the insured value of structures carried by one or more insurers.

Fault – A fracture in the earth's crust accompanied by displacement of one side of the fracture with respect to the other in a direction parallel to the fracture.

Focus – The location of a fault break where an earthquake originates; also termed "hypocenter."

Force – Agency or influence that tries to deform an object or overcome its resistance to motion.

Frame, Braced – Diagonal members connecting together components of a structural frame in such a way as to resist lateral forces.

Frame System, Building – A structural system with an essentially complete space frame providing support for vertical loads; seismic forces are resisted by shear walls or braced frames.

Frame System, Moment – A space frame in which members and joints are capable of resisting lateral forces by bending as well as along the axis of the members; varying levels of resistance are provided by ordinary, intermediate and special moment frames as defined in the *Provisions* with special frames providing the most resistance.

Frame, Space – A structural system composed of interconnected members, other than bearing walls, that is capable of supporting vertical loads and that also may provide resistance to seismic forces.

"g" – The acceleration due to gravity or 32 feet per second per second.

Ground Failure – Physical changes to the ground surface produced by an earthquake such as lateral spreading, landslides, or liquefaction.

Hypocenter – See "Focus."

Intensity – The apparent effect that an earthquake produces at a given location; in the United States, intensity generally is measured by the modified Mercalli intensity (MMI) scale.

Irregular – Deviation of a building configuration from a simple symmetrical shape.

Joint – Location of connections between structural or nonstructural members and components.

Liquefaction – The conversion of a solid into a liquid by heat, pressure, or violent motion; sometimes occurs to the ground in earthquakes.

Load, Dead – The gravity load created by the weight of all permanent structural and nonstructural building components such as walls, floors, roofs, and fixed service equipment.

Load, Live – Moving or movable external loading on a structure; it includes the weight of people, furnishings, equipment, and other items not permanently attached to the structure.

Loss – Any adverse economic or social consequences caused by earthquakes.

Mass – A constant quantity or aggregate of matter; the inertia or sluggishness that an object, when frictionlessly mounted, exhibits in response to any effort made to start it or stop it or to change in any way its state of motion.

Mercalli Scale (or Index) – A measure of earthquake intensity named after Giuseppe Mercalli, an Italian priest and geologist.

Partition – See "Wall, Nonbearing."

Period – The elapsed time (generally in seconds) of a single cycle of a vibratory motion or oscillation; the inverse of frequency.

P-Wave – The primary or fastest waves traveling away from a fault rupture through the earth's crust and consisting of a series of compressions and dilations of the ground material.

Recurrence Interval – See "Return Period."

Resonance – The amplification of a vibratory motion occurring when the period of an impulse or periodic stimulus coincides with the period of the oscillating body.

Return Period – The time period in years in which the probability is 63 percent that an earthquake of a certain magnitude will recur.

Richter Magnitude (or Scale) – A logarithmic scale expressing the magnitude of a seismic (earthquake) disturbance in terms of the maximum amplitude of the seismic waves at a standard distance from their focus named after its creator, the American seismologist Charles R. Richter.

Rigidity – Relative stiffness of a structure or element; in numerical terms, equal to the reciprocal of displacement caused by unit force.

Seismic – Of, subject to, or caused by an earthquake or an earth vibration.

Seismic Event – The abrupt release of energy in the earth's lithosphere causing an earth vibration; an earthquake.

Seismic Forces – The actual forces created by earthquake motion; assumed forces prescribed in the *Provisions* that are used in the seismic design of a building and its components.

Seismic Hazard – any physical phenomenon such as ground shaking or ground failure associated with an earthquake that may produce adverse effects on the built environment and human activities; also the probability of earthquakes of defined magnitude or intensity affecting a given location.

Seismic Hazard Exposure Group – A classification assigned in the *Provisions* to a building based on its occupancy and use.

Seismic Performance Category – A classification assigned in the *Provisions* based on its Seismic Hazard Exposure Group and its seismic hazard.

Seismic Force Resisting System – The part of the structural system that is designed to provide required resistance to prescribed seismic forces.

Seismic Risk – The probability that the social or economic consequences of an earthquake will equal or exceed specified values at a site during a specified exposure time; in general, seismic risk is vulnerability multiplied by the seismic hazard.

Seismic Waves – See "Waves, Seismic."

Seismic Zone – Generally, areas defined on a map within which seismic design requirements are constant; in the *Provisions*, seismic zones are defined both by contour lines and county boundaries.

Shear – A force that acts by attempting to cause the fibers or planes of an object to slide over one another.

Shear Panel – See "Wall, Shear."

Shear Wall – See "Wall, Shear."

Speed – Rate of change of distance traveled with time irrespective of direction.

Stiffness – Resistance to deflection or drift of a structural component or system.

Story Drift – Vertical deflection of a single story of a building caused by lateral forces.

Strain – Deformation of a material per unit of the original dimension.

Strength – The capability of a material or structural member to resist or withstand applied forces.

Stress – Applied load per unit area or internal resistance within a material that opposes a force's attempts to deform it.

S-Wave – Shear or secondary wave produced essentially by the shearing or tearing motions of earthquakes at right angles to the direction of wave propagation.

System – An assembly of components or elements designed to perform a specific function such as a structural system.

Torque – The action of force that tends to produce torsion; the product of a force and lever arm as in the action of using a wrench to tighten a nut.

Torsion – The twisting of a structural member about its longitudinal axis.

Velocity – Rate of change of distance travelled with time in a given direction; in earthquakes, it usually refers to seismic waves and is expressed in inches or centimeters per second.

Vulnerability – The degree of loss to a given element at risk, or set of such elements, resulting from an earthquake of a given intensity or magnitude; expressed in a scale ranging from no damage to total loss; a measure of the probability of damage to a structure or a number of structures.

Wall, Bearing – An interior or exterior wall providing support for vertical loads.

Wall, Nonbearing – An interior or exterior wall that does not provide support for vertical loads other than its own weight as permitted by the building code; see also "Partition. "

Wall, Shear – A wall, bearing or nonbearing, designed to resist seismic forces acting in the plane of the wall.

Wall System, Bearing – A structural system with bearing walls providing support for all or major portions of the vertical loads; seismic resistance may be provided by shear walls or braced frames.

Waves, Seismic – Vibrations in the form of waves created in the earth by an earthquake.

Weight – Name given to the mutual gravitational force between the earth and an object under consideration; varies depending on location of the object at the surface of the earth.

GENERAL TERMS

The following excerpt from the National Research Council Report, *Multiple Hazard Mitigation* (Washington, D.C.: National Academy Press, 1983), defines several other terms that sometimes cause confusion in discussions of seismic safety:

> ". . . The level of intensity or severity that is capable of causing damage depends upon the vulnerability of the exposed community; vulnerability is generally a function of the way in which structures are designed, built, and protected, and the vulnerability of a structure or community to a particular natural event is a measure of the damage likely to be sustained

should the event occur. The degree to which a community is prone to a particular natural hazard depends on risk, exposure, and vulnerability. When a natural hazard occurrence significantly exceeds the community's capacity to cope with it, or causes a large number of deaths and injuries or significant economic loss, it is called a disaster.

Hazard management includes the full range of organized actions undertaken by public and private organizations in anticipation of and in response to hazards. Hazard management has two primary (but not completely distinct) components: emergency management, typified by the police, fire, rescue, and welfare work carried on during a disaster; the advance planning and training that are necessary if emergency operations are to be carried out successfully; and the post-disaster recovery period in which damage is repaired; and mitigation, which focuses on planning, engineering, design, economic measures, education, and information dissemination, all carried out for the purpose of reducing the long-term losses associated with a particular hazard or set of hazards in a particular location."