







|          | Seismic Ha<br>Shakin              | azard<br>Ig irrespe | ective of c                | Instructor: Dr. C.E. Ventura |  |  |  |  |
|----------|-----------------------------------|---------------------|----------------------------|------------------------------|--|--|--|--|
|          | Seismic Risk<br>Hazard * Exposure |                     |                            |                              |  |  |  |  |
| <u>₽</u> | Baffin Island                     | hazard *            | exposure                   | <u>= risk</u>                |  |  |  |  |
|          | Vancouver                         | high                | high                       | high                         |  |  |  |  |
|          | Toronto                           | low                 | high                       | moderate                     |  |  |  |  |
| Ö        | V                                 | Seismic Design o    | of Multistorey Concrete St | ructures<br>No. 5            |  |  |  |  |





## Introduction – Plate Tectonics

• The Earth is characterized by a small number of lithospheric plates that float on a viscous underlayer called the asthenosphere.

 Geological evidence shows that plates undergo constant, gradual change. Magma is continually upwelling at the mid-oceanic ridges and rises as the seafloor spreads apart.

• In some areas, large sections of plates are forced to move beneath other plates (surface layers of rocks are absorbed into the earth's interior). These areas are called subduction zones.











| Descriptor              | Magnitude      | Average Annually         |  |
|-------------------------|----------------|--------------------------|--|
| Great                   | 8 and higher   | 1 <sup>1</sup>           |  |
| Major                   | 7 - 7.9        | 17 <sup>2</sup>          |  |
| Strong                  | 6 - 6.9        | 134 ²                    | Globally, Each Year:                                 |
| Moderate                | 5 - 5.9        | 1319 <sup>2</sup>        | ~100,000 earthquakes can be fel<br>~100 cause damage |
| Light                   | 4 - 4.9        | 13,000<br>(estimated)    |  |
| Minor                   | 3 - 3.9        | 130,000<br>(estimated)   | Source:<br>USGS, 2005                                |
| Very Minor              | 2 - 2.9        | 1,300,000<br>(estimated) |  |
| <sup>1</sup> Based on o | observations s | since 1900.<br>ince 1990 |  |































|               |            |           |              | 1  | structor: Dr. C.E. Vontura  |
|---------------|------------|-----------|--------------|--|-----------------------------|
|               |            |           |              | •  | Istructor. Dr. C.E. Ventura |
|               | Intensity, | PGAs      | and Effe     | cts                                      |                             |
|               | • •        |           |              |  |                             |
|               |            |           |              |  |                             |
|               |            | Modified  |              |  |                             |
|               |            | Mercalli  | Peak Ground  |  |                             |
|               |            | Intensity | Acceleration | Typical Effects                          |                             |
|               |            | I         |              | Not felt                                 |                             |
|               |            | II        |              | Felt by few                              |                             |
|               |            | III       |              | Light shaking                            |                             |
|               |            | IV        | 0.02g        | Windows rattle                           |                             |
|               |            | V         | 0.04g        | Sleepers awakened                        |                             |
|               |            | VI        | 0.07g        | Small objects fall off shelves           |                             |
| ā             |            | VII       | 0.15g        | Masonry damaged                          |                             |
|               |            | VIII      | 0.30g        | Chimneys fall                            |                             |
| $ rac{1}{2} $ |            | IX        | 0.50g        | Substantial building damage              |                             |
| $\square$     |            | Х         | 0.60g        | Many structures heavily damaged          |                             |
|               |            | XI        |              | Many structures destroyed                |                             |
|               |            | XII       |              | Total damage                             |                             |
|               |            |           | •            |  | -                           |
| <b>OBC</b>    | CSCE       |           | Seismic De   | esign of Multistorey Concrete Structures |                             |





























































































| S <sub>a</sub> (1.0)<br>0.060 R<br>0.070 R<br>0.068 H<br>0.086 H<br>0.60 H<br>0.14 H<br>0.12 R<br>0.14 R | S <sub>p</sub> (2.0)<br>0.016 R<br>0.019 R<br>0.021 H<br>0.027 H<br>0.027 H<br>0.048 H<br>0.048 R              | PGA<br>0.090 R<br>0.12 R<br>0.21 H<br>0.27 R<br>1.1 H<br>0.37 R<br>0.40 R   | PGV<br>0.057 R<br>0.071 R<br>0.095 H<br>0.12 R<br>0.62 H<br>0.16 R | S <sub>8</sub> (0.2)<br>0.31 R<br>0.41 R<br>0.52 H<br>0.69 R<br>3.8 H<br>3.8 H   | S <sub>a</sub> (0.5)<br>0.29 R<br>0.34 R<br>0.42 H<br>0.52 R<br>3.1 H | S <sub>a</sub> (1.0)<br>0.16 R<br>0.18 R<br>0.22 H<br>0.27 R | S <sub>a</sub> (2.0)                                  | PGA<br>0.14 F<br>0.19 R<br>0.30 H                     | PG<br>0.1<br>0.1 |
|--|--|---|--|--|---|--|---|---|------------------|
| 0.060 R<br>0.070 R<br>0.068 H<br>0.086 H<br>0.60 H<br>0.14 H<br>0.12 R<br>0.14 R<br>0.14 R               | 0.016 R<br>0.019 R<br>0.021 H<br>0.027 H<br>0.027 H<br>0.048 H<br>0.048 R                                      | 0.090 R<br>0.12 R<br>0.21 H<br>0.27 R<br>1.1 H<br>0.37 R<br>0.40 R  | 0.057 R<br>0.071 R<br>0.095 H<br>0.12 R<br>0.62 H<br>0.16 R        | 0.31 R<br>0.41 R<br>0.52 H<br>0.69 R<br>3.8 H  | 0.29 R<br>0.34 R<br>0.42 H<br>0.52 R<br>3.1 H                         | 0.16 R<br>0.18 R<br>0.22 H<br>0.27 R                         |   | 0.14 F<br>0.19 R<br>0.30 H                            | 0.1              |
| 0.070 R<br>0.068 H<br>0.086 H<br>0.60 H<br>0.14 H<br>0.12 R<br>0.14 R<br>0.14 R                          | 0.019 R<br>0.021 H<br>0.027 H<br>0.19 H<br>0.048 H<br>0.043 R<br>0.048 R                                       | 0.12 R<br>0.21 H<br>0.27 R<br>1.1 H<br>0.37 R<br>0.40 R   | 0.071 R<br>0.095 H<br>0.12 R<br>0.62 H<br>0.16 R                   | 0.41 R<br>0.52 H<br>0.69 R<br>3.8 H  | 0.34 R<br>0.42 H<br>0.52 R<br>3.1 H                                   | 0.18 R<br>0.22 H<br>0.27 R                                   |   | 0.19 R<br>0.30 H                                      | 0.1              |
| 0.068 H<br>0.086 H<br>0.60 H<br>0.14 H<br>0.12 R<br>0.14 R<br>0.14 R                                     | 0.021 H<br>0.027 H<br>0.19 H<br>0.048 H<br>0.043 R<br>0.048 R  | 0.21 H<br>0.27 R<br>1.1 H<br>0.37 R<br>0.40 R   | 0.095 H<br>0.12 R<br>0.62 H<br>0.16 R                              | 0.52 H<br>0.69 R<br>3.8 H  | 0.42 H<br>0.52 R<br>3.1 H   | 0.22 H<br>0.27 R   |   | 0.30 H  |                  |
| 0.086 H<br>0.60 H<br>0.14 H<br>0.12 R<br>0.14 R<br>0.14 R  | 0.027 H<br>0.19 H<br>0.048 H<br>0.043 R<br>0.048 R   | 0.27 R<br>1.1 H<br>0.37 R<br>0.40 R   | 0.12 R<br>0.62 H<br>0.16 R   | 0.69 R<br>3.8 H  | 0.52 R<br>3.1 H   | 0.27 R   |   |   | 0.2              |
| 0.60 H<br>0.14 H<br>0.12 R<br>0.14 R<br>0.14 R   | 0.19 H<br>0.048 H<br>0.043 R<br>0.048 R  | 1.1 H<br>0.37 R<br>0.40 R   | 0.62 H<br>0.16 R   | 3.8 H  | 3.1 H   |  |   | 0.38 R  | 0.3              |
| 0.14 H<br>0.12 R<br>0.14 R<br>0.14 R   | 0.048 H<br>0.043 R<br>0.048 R  | 0.37 R<br>0.40 R  | 0.16 R   | 10 D   |   | 1.8 H  |   | 2.0 H   | 1.5              |
| 0.12 R<br>0.14 R<br>0.14 R   | 0.043 R  | 0.40 R  |  | 1.0 K  | 0.75 H  | 0.44 H   |   | 0.57 R  | 0.4              |
| 0.14 R<br>0.14 R   | 0.048 R  |   | 0.17 R   | 1.1 R  | 0.77 R  | 0.40 R   |   | 0.62 R  | 0,4              |
| 0.14 R   | 070-40 Ft  | 0.43 R  | 0.18 R   | 1.2 R  | 0.83 R  | 0.44 R   |   | 0.63 R  | 0.4              |
|  | 0.045 R  | 0.42 R  | 0.18 R   | 1.1 R  | 0.80 R  | 0.42 R   |   | 0.63 R  | 0,4              |
| 0.073 H  | 0.021 H  | 0.30 H  | 0.13 H   | 0.93 H   | 0.52 H  | 0.25 H   |   | 0.48 H  | 0.3              |
| 0.055 R  | 0.016 H  | 0.20 H  | 0.083 H  | 0.56 H   | 0.35 H  | 0.17 H   |   | 0.28 H  | 0.3              |
| 0.040 R  | 0.011 R  | 0.12 R  | 0.055 R  | 0.32 R   | 0.22 R  | 0.11 R   |   | 0.19 R  | 0,               |
| 0.023 F  | 0.006 F  | 0.059 F   | 0.040 F  | 0.21 F   | 0.17 F  | 0.079 F  |   | 0.14 F  | 0.               |
| 0.041 H  | 0.023 H  | 0.088 H   |  | 0.29 H   | 0.17 H  | 0.080 H  | 0.045 H   | 0.18 H  |                  |
| 0.089 R  | 0.053 R  | 0.14 H  |  | 0.55 H   | 0.34 H  | 0.18 R   | 0.11 R  | 0.27 H  |                  |
| 0.10 R   | 0.060 R  | 0.14 H  |  | 0.55 H   | 0.34 H  | 0.20 R   | 0.12 R  | 0.27 H  |                  |
| 0.041 R  | 0.026 R  | 0.071 H   |  | 0.26 H   | 0.17 F  | 0.080 H  | 0.052 R   | 0.14 H  |                  |
| 0.34 R   | 0.18 R   | 0.48 H  |  | 1.9 H  | 1.3 R   | 0.68 R   | 0.35 R  | 0.96 H  |                  |
| 0.38 H   | 0.19 R   | 0.62 H  |  | 2.5 H  | 1.7 H   | 0.77 H   | 0.37 R  | 1.2 H   |                  |
| 0.47 C   | 0.21 C   | 0.52 C  |  | 2.3 C  | 1.8 C   | 0.90 C   | 0.44 C  | 1.0 C   |                  |
| 0.17 R   | 0.096 R  | 0.18 R  |  | 0.75 R   | 0.50 R  | 0.33 R   | 0.19 R  | 0.36 R  |                  |
| 0.50 R   | 0.26 R   | 0.36 R  |  | 1.3 R  | 1.2 R   | 1.0 R  | 0.53 R  | 0.71 R  |                  |
| 0.020 P  |  |   |  |  |   |  |   |   |                  |
|  | 0.040 R<br>0.023 F<br>0.041 H<br>0.089 R<br>0.10 R<br>0.34 R<br>0.34 R<br>0.38 H<br>0.37 C<br>0.17 R<br>0.50 R | 0.033 R 0.010 H<br>0.040 R 0.011 R<br>0.023 F 0.006 F<br>0.041 H 0.023 H<br>0.089 R 0.053 R<br>0.10 R 0.060 R<br>0.34 R 0.18 R<br>0.34 R 0.19 R<br>0.47 C 0.21 C<br>0.17 R 0.096 R<br>0.50 R 0.26 R | $\begin{array}{cccccccccccccccccccccccccccccccccccc$               | 0.053 R 0.016 R 0.23 H 0.085 R<br>0.023 F 0.006 F 0.059 F 0.040 F<br>0.023 F 0.006 F 0.059 F 0.040 F<br>0.039 R 0.053 R 0.14 H<br>0.089 R 0.053 R 0.14 H<br>0.041 R 0.025 R 0.071 H<br>0.34 R 0.18 R 0.48 H<br>0.35 R 0.19 R 0.62 H<br>0.47 C 0.21 C 0.52 C<br>0.17 R 0.096 R 0.18 R<br>0.50 R 0.26 R 0.36 R | $\begin{array}{cccccccccccccccccccccccccccccccccccc$                  | $      \begin{array}{ccccccccccccccccccccccccccccccc$        | $      \begin{array}{ccccccccccccccccccccccccccccccc$ | $      \begin{array}{ccccccccccccccccccccccccccccccc$ |                  |

| mnle "Rohust" l  | کمر                              | ian   | Nata  |   |  |  |  |  |
|--|----------------------------------|---|---|---|--|--|--|--|
|  | 203                              | 'g'i '  | Data  |   |  |  |  |  |
|  |                                  |   |   |   |  |  |  |  |
|  |                                  | _   | <b>F</b> 1 1  | 1   |  |  |  |  |
|  |                                  |   | lable   | 1   |  |  |  |  |
| Seismic haza   | rd valı                          | les inter   | nded for th   | ie 2005 N   | BCC "De  | sign Data  |  |  |
|  | for Se                           | lected L  | ocations i  | n Canada  | " table  |  |  |  |
| Notes Peak and spectral hazard   | values a                         | re determ   | ined for an   | vceedence   | of 2%/50 ve  | ars Value  | s are for "f                                 | ĩm   |
| ground" (NBCC 2005 soil class C  | - avera                          | ge shear w  | ave velocit   | y 360-750 n                                       | n/s). Media  | n (50th perc   | centile) val                                 | ues are                                      |
| given in units of g for peak horizon   | ntal and                         | 5% damp   | ed spectral   | horizontal a                                      | acceleration.  |  |  |  |
| Locality   |                                  | L at N  | Lon W   | Sa(0.2)   | Sa(0.5)  | Sa(1.0)  | Sa(2.0)                                      | PC A   |
| Locality   |                                  | Latin   | LOI W   | 5a(0.2)   | Sa(0.5)  | Sa(1.0)  | Sa(2.0)                                      | rGA  |
| 100 Mile House   | BC                               | 51.50   | -121.28   | 0.28  | 0.17   | 0.11   | 0.063  | 0.14   |
| Abbotsford   | BC                               | 49.10   | -122.25   | 0.92  | 0.62   | 0.31   | 0.17   | 0.45   |
| Agassiz  | BC                               | 49.23   | -121.77   | 0.67  | 0.50   | 0.29   | 0.16   | 0.32   |
| Alberni  | BC                               | 49.27   | -124.80   | 0.75  | 0.55   | 0.30   | 0.16   | 0.35   |
|  | BC                               | 49.08   | -123.08   | 1.1   | 0.73   | 0.35   | 0.18   | 0.54   |
| Ladner   |                                  |   |   |   |  |  | 0.17   | 0.53   |
| Ladner<br>Langley  | BC                               | 49.10   | -122.65   | 1.1   | 0.71   | 0.33   | 0.17   |  |
| Ladner<br>Langley<br>New Westminster   | BC<br>BC                         | 49.10<br>49.22  | -122.65<br>-122.92  | 1.1<br>0.99                                       | 0.71<br>0.66   | 0.33   | 0.17   | 0.49   |
| Ladner<br>Langley<br>New Westminster<br>North Vancouver  | BC<br>BC<br>BC                   | 49.10<br>49.22<br>49.32                                     | -122.65<br>-122.92<br>-123.07   | 1.1<br>0.99<br>0.88                               | 0.71<br>0.66<br>0.61                                 | 0.33<br>0.33<br>0.33                                 | 0.17   | 0.49   |
| Ladner<br>Langley<br>New Westminster<br>North Vancouver<br>Richmond  | BC<br>BC<br>BC<br>BC             | 49.10<br>49.22<br>49.32<br>49.17                            | -122.65<br>-122.92<br>-123.07<br>-123.10                                  | 1.1<br>0.99<br>0.88<br>1.0                        | 0.71<br>0.66<br>0.61<br>0.68                         | 0.33<br>0.33<br>0.33<br>0.34                         | 0.17<br>0.17<br>0.18                         | 0.49<br>0.44<br>0.50                         |
| Ladner<br>Langley<br>New Westminster<br>North Vancouver<br>Richmond<br>Surrey (88 Ave. & 156 St.)  | BC<br>BC<br>BC<br>BC<br>BC       | 49.10<br>49.22<br>49.32<br>49.17<br>49.17                   | -122.65<br>-122.92<br>-123.07<br>-123.10<br>-122.78                       | 1.1<br>0.99<br>0.88<br>1.0<br>1.0                 | 0.71<br>0.66<br>0.61<br>0.68<br>0.69                 | 0.33<br>0.33<br>0.33<br>0.34<br>0.33                 | 0.17<br>0.17<br>0.18<br>0.17                 | 0.49<br>0.44<br>0.50<br>0.51                 |
| Ladner<br>Langley<br>New Westminster<br>North Vancouver<br>Richmond<br>Surrey (88 Ave. & 156 St.)<br>Vancouver                                   | BC<br>BC<br>BC<br>BC<br>BC<br>BC | 49.10<br>49.22<br>49.32<br>49.17<br>49.17<br>49.25          | -122.65<br>-122.92<br>-123.07<br>-123.10<br>-122.78<br>-123.12            | 1.1<br>0.99<br>0.88<br>1.0<br>1.0<br>0.94         | 0.71<br>0.66<br>0.61<br>0.68<br>0.69<br>0.64         | 0.33<br>0.33<br>0.33<br>0.34<br>0.33<br>0.33         | 0.17<br>0.17<br>0.18<br>0.17<br>0.17         | 0.49<br>0.44<br>0.50<br>0.51<br>0.46         |
| Ladner<br>Langley<br>New Westminster<br>North Vancouver<br>Richmond<br>Surrey (88 Ave. & 156 St.)<br>Vancouver<br>Vancouver (Granville & 41 Ave) | BC<br>BC<br>BC<br>BC<br>BC<br>BC | 49.10<br>49.22<br>49.32<br>49.17<br>49.17<br>49.25<br>49.23 | -122.65<br>-122.92<br>-123.07<br>-123.10<br>-122.78<br>-123.12<br>-123.13 | 1.1<br>0.99<br>0.88<br>1.0<br>1.0<br>0.94<br>0.95 | 0.71<br>0.66<br>0.61<br>0.68<br>0.69<br>0.64<br>0.65 | 0.33<br>0.33<br>0.33<br>0.34<br>0.33<br>0.33<br>0.33 | 0.17<br>0.17<br>0.18<br>0.17<br>0.17<br>0.17 | 0.49<br>0.44<br>0.50<br>0.51<br>0.46<br>0.47 |



| Instructor: Dr. C.E. Ventura   |
|--|
| Final remarks  |
|  |
| The seismic hazard results generated from the new national model will provide a more reliable basis for seismic design of new buildings across Canada. |
| They provide an updated depiction of hazard across Canada, including its variability with spectral period.   |
| The spectral parameters used will describe the expected shaking better than the peak motion parameters used in the 1995 NBCC.                          |
| Understanding of the new results will be aided by new ways of presenting the information, such as deaggregation.                                       |
| More reliable hazard values for future building codes will arise from reducing the epistemic uncertainty wherever possible                             |
|  |
| Seismic Design of Multistorey Concrete Structures  |

