Hazard Mitigation and Disaster Management (HMDM) Research Centre

uOttawa

L'Université canadienne
Canada's university

How Safe is Our Infrastructure?

Earthquakes and Bomb Blasts…

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Department of Civil Engineering
University of Ottawa

- Mitigation
- Prevention
- Protection
- Monitoring
- Security
- Preparedness
- Education
- Response
- Relief
- Recovery
- Reconstruction

How Many Earthquakes Occur Worldwide Each Year?

Description	Magnitude	Annual Average
Great	8 or higher	1
Major	7 – 7.9	18
Strong	6 – 6.9	120
Moderate	5 – 5.9	800
Light	4 – 4.9	6,200
Minor	3 – 3.9	49,000
Very Minor	2 – 3	1,000/day
Very Minor	1 – 2	8,000/day

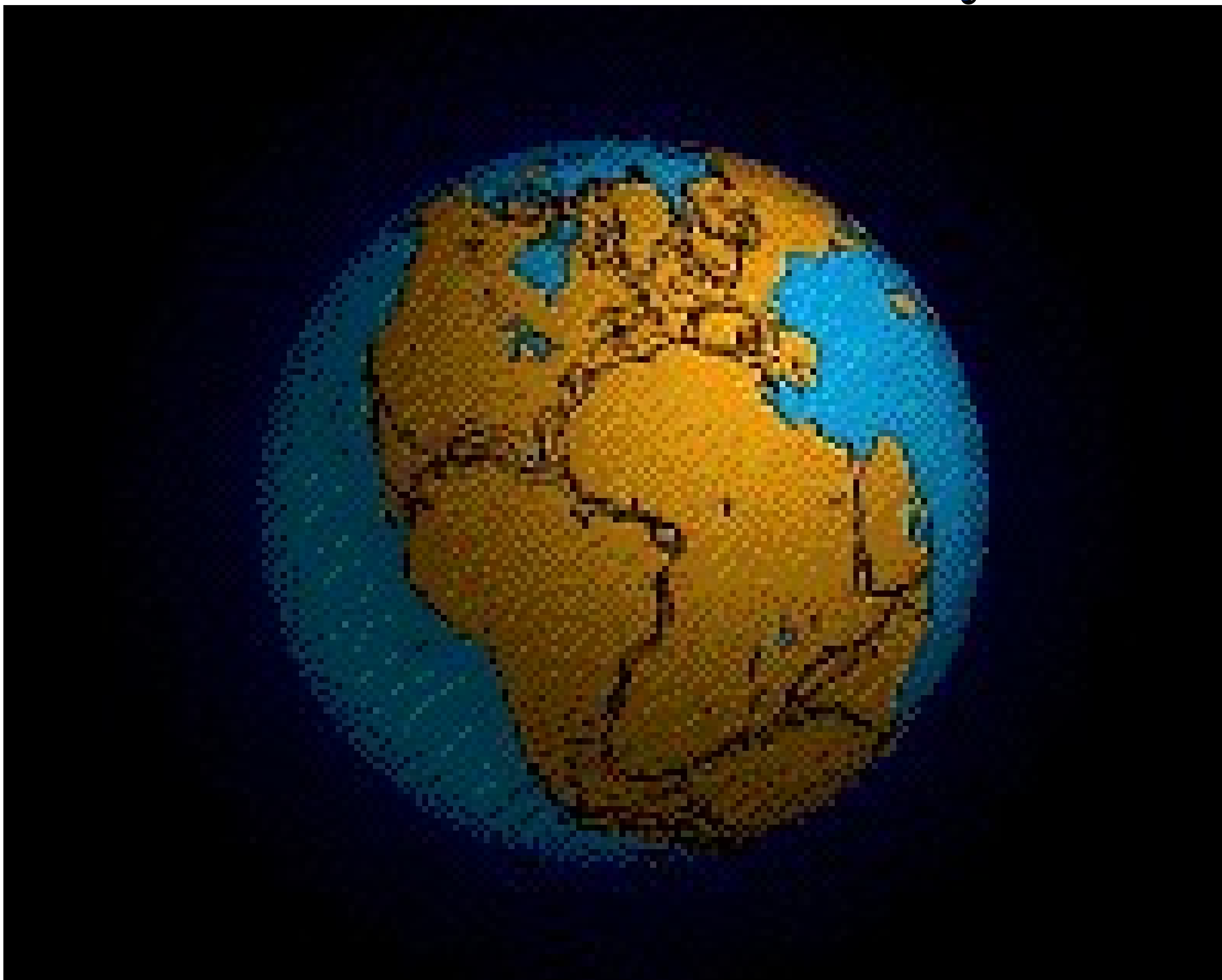




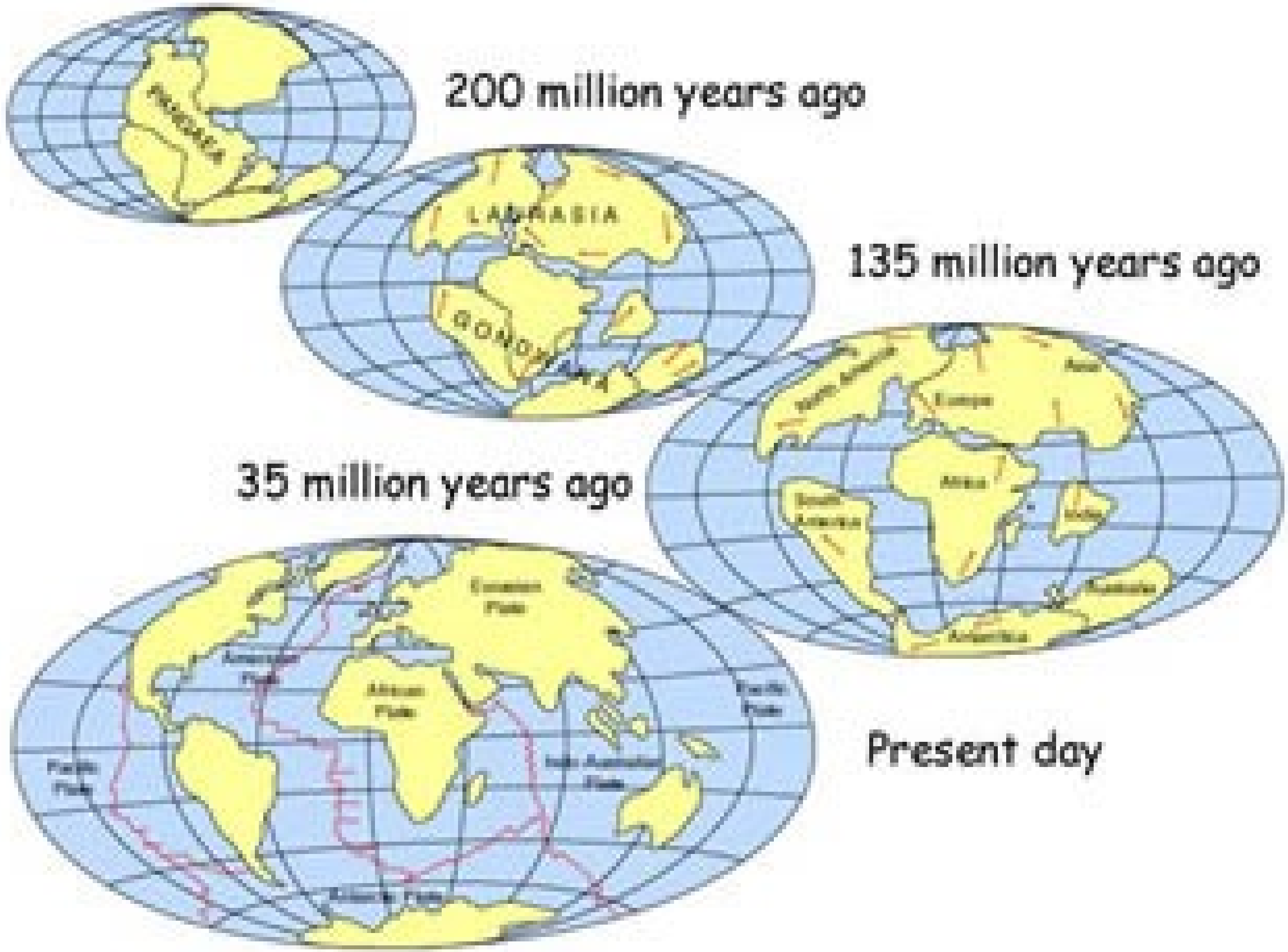


Causes of Earthquakes

Continental Drift Theory

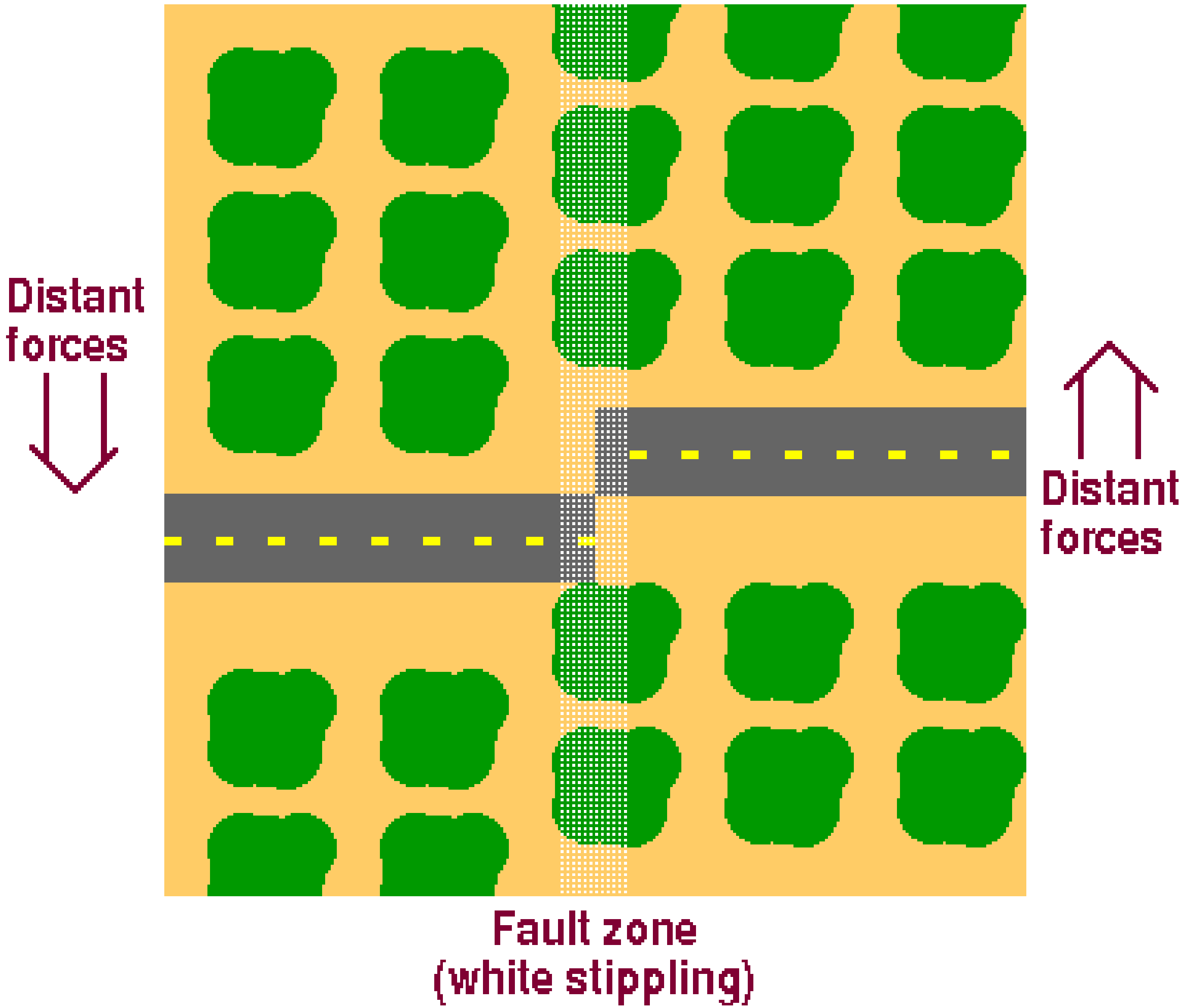


Causes of Earthquakes
Continental Drift Theory



Earthquakes Between 1960 and 1995

Earthquake!!!



Fault Rupture

Fault Rupture

Vertical Offset Due to Fault Rupture

1977 Caucete E.Q. in Argentina

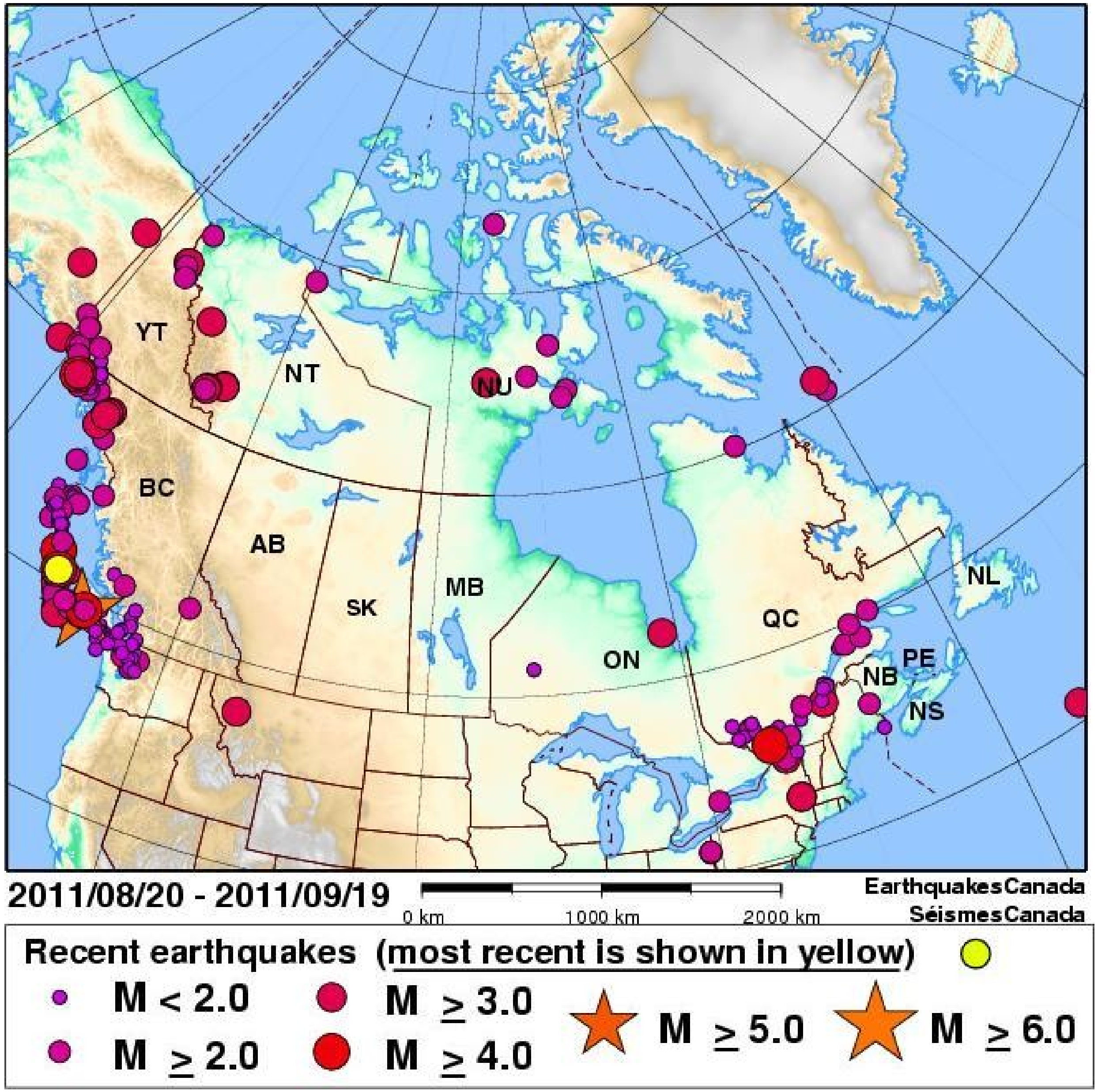
Fault Rupture

How Many Earthquakes Occur in Canada?

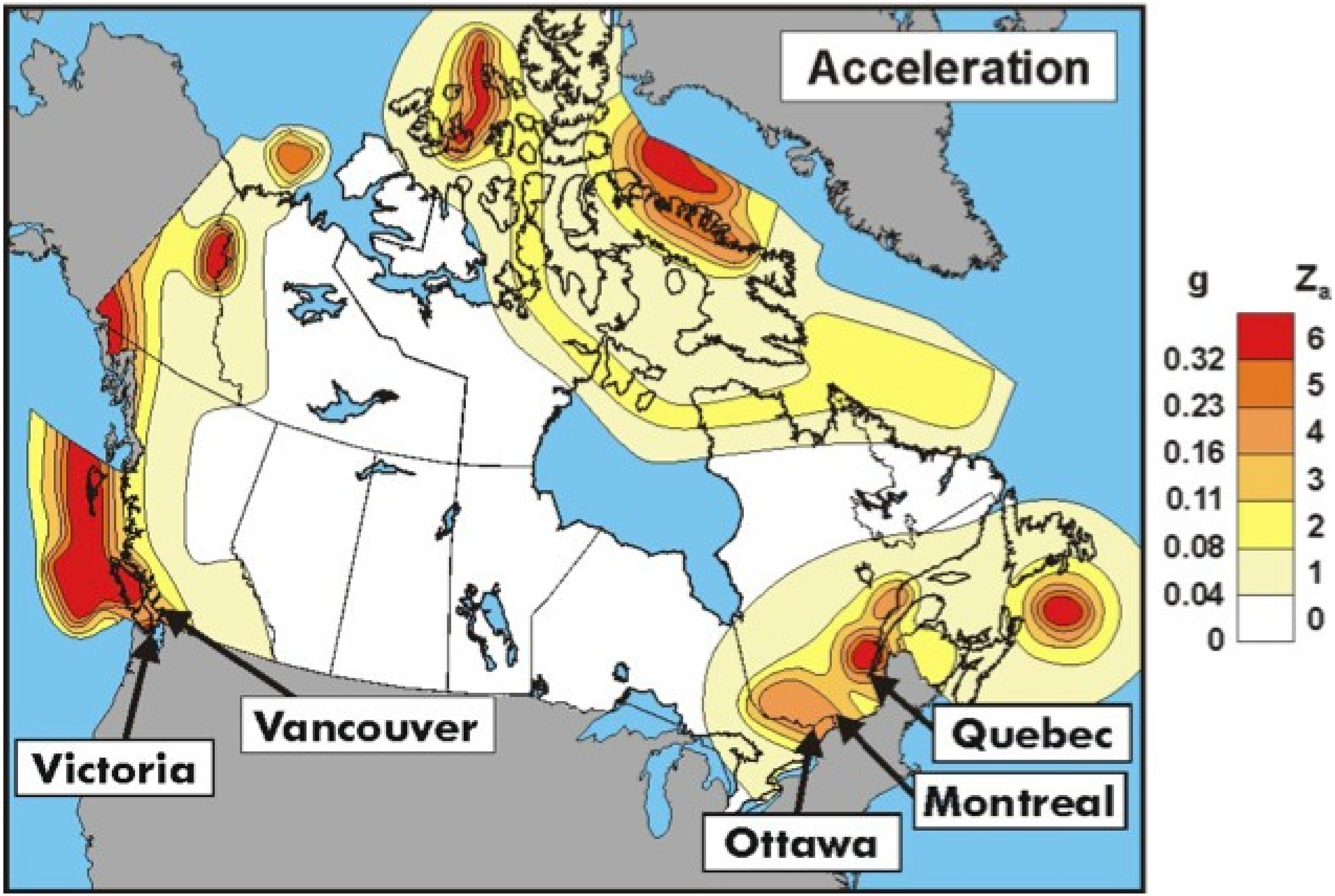
More than 4000 earthquakes are recorded each year in Canada

Approximately 300 earthquakes occur each year in Eastern Canada. Of this number, approximately four exceeds magnitude 4.0

Earthquakes That Occurred in the Last 30 Days



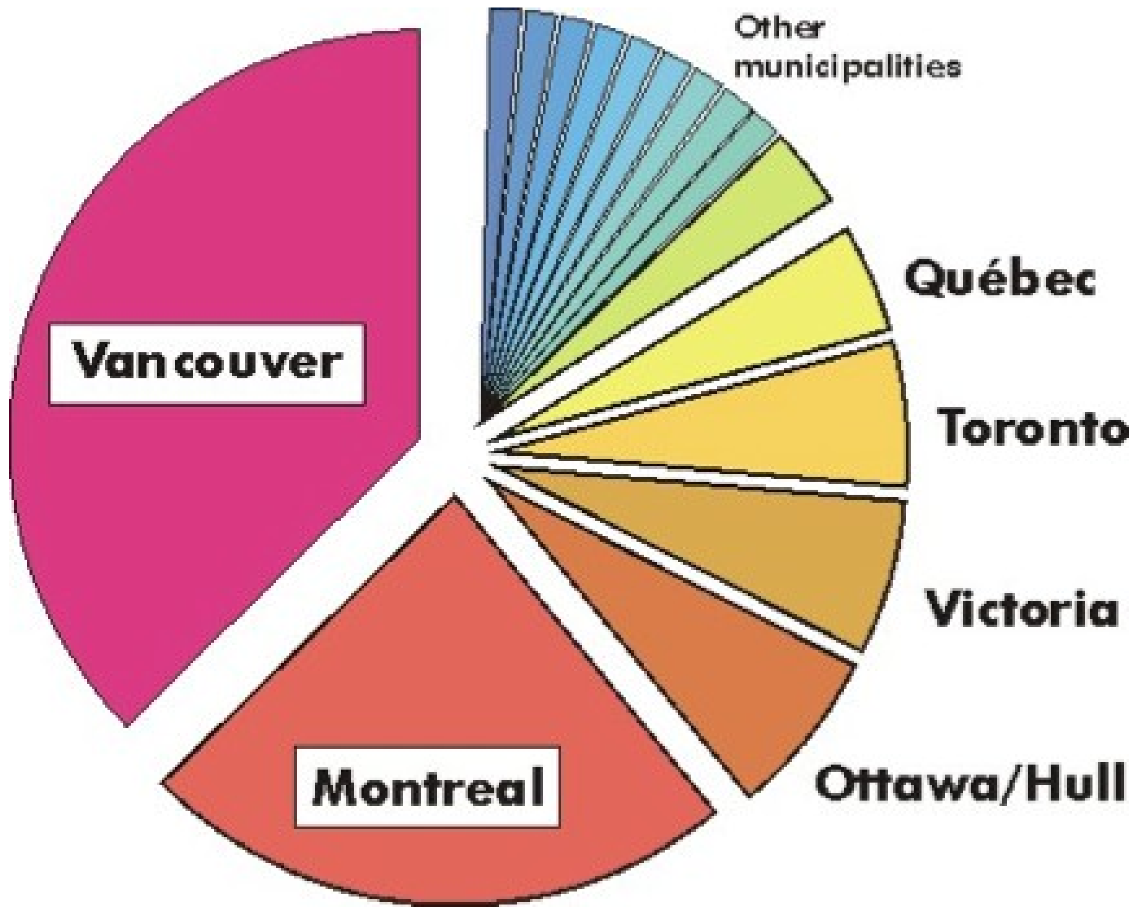
Seismic Hazard in Canada



by GSC

Seismic Risk in Canada

Seismic Risk = Hazard * Vulnerability * Exposure



by GSC

Seismic Risk in Canada

"the major threat to public safety in the Montréal region is the threat from seismic events"

Centre de Securité Civile de Montréal (2005)

"total economic loss from a major earthquake in the Lower Mainland of BC is estimated between $14 and $32 billion"

Munich Reinsurance Company of Canada (1992)

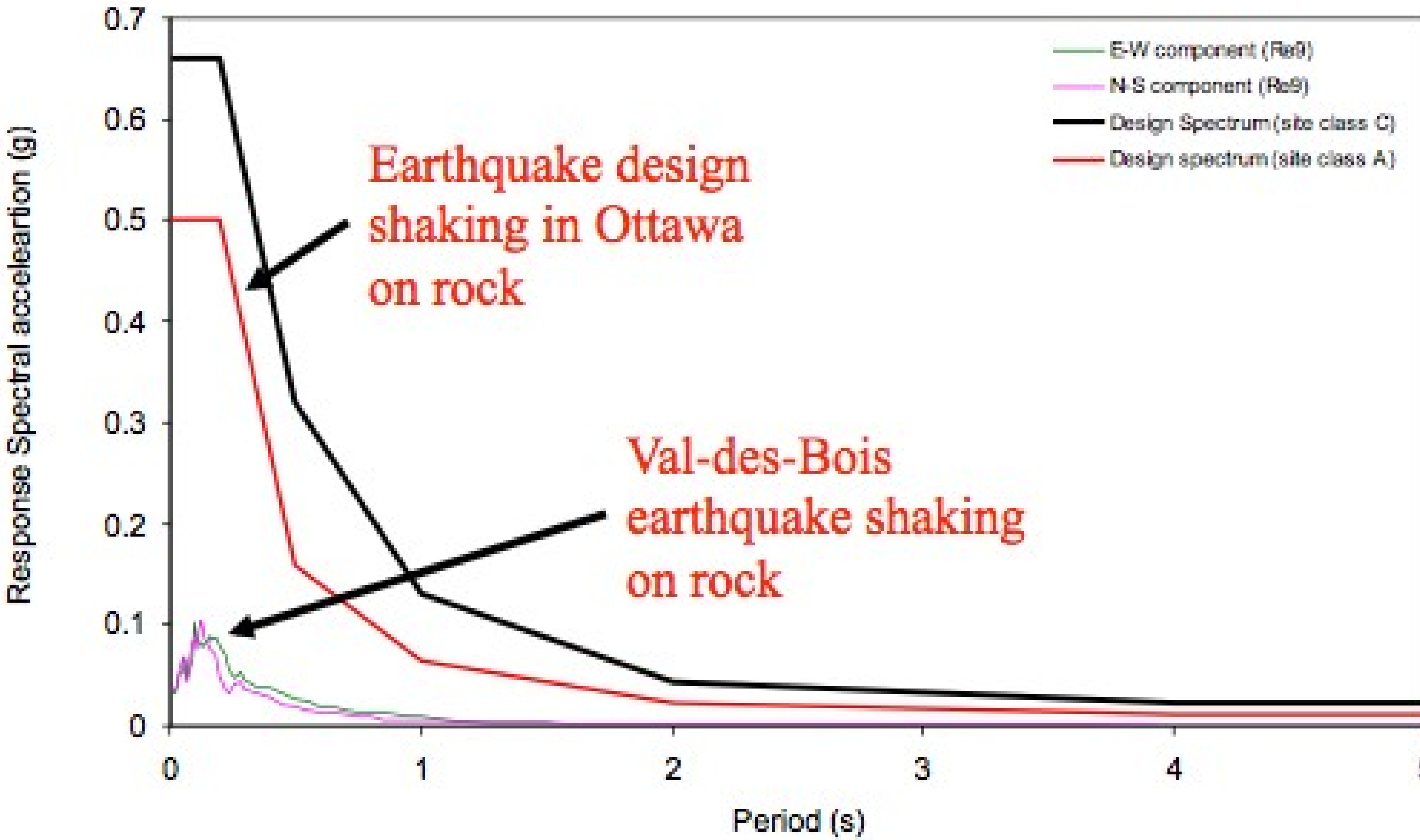
A major earthquake is the single largest threat to public safety and security in many Canadian cities and would result in major economic losses

Seismic Vulnerability of Buildings

- Building designed and built prior to the enactment of modern seismic codes may be vulnerable against seismic motions. In Canada, this means buildings prior to 1970's and 1980's.
- Buildings on soft soil are more vulnerable than those built on solid rock.

Effect of Soil Conditions

The effect of ground motion is amplified by soil soft



Liquefaction

Liquefaction







Liquefaction

Seismic Vulnerability of Buildings

- Buildings constructed using **brittle** construction materials are more vulnerable than those built using **ductile** materials
- Typically, old masonry and non-ductile reinforced concrete buildings behave in a brittle manner
- Steel construction, well-designed reinforced concrete buildings and single-family timber houses often perform favorably





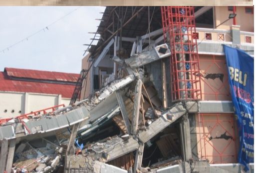


2010 Earthquake in Chile

2010 Earthquake in Chile

2010 Earthquake in Chile

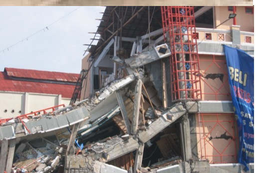
2010 Earthquake in Chile




May 12, 2008 Wenchuan Earthquake in China

May 12, 2008 Wenchuan Earthquake in China

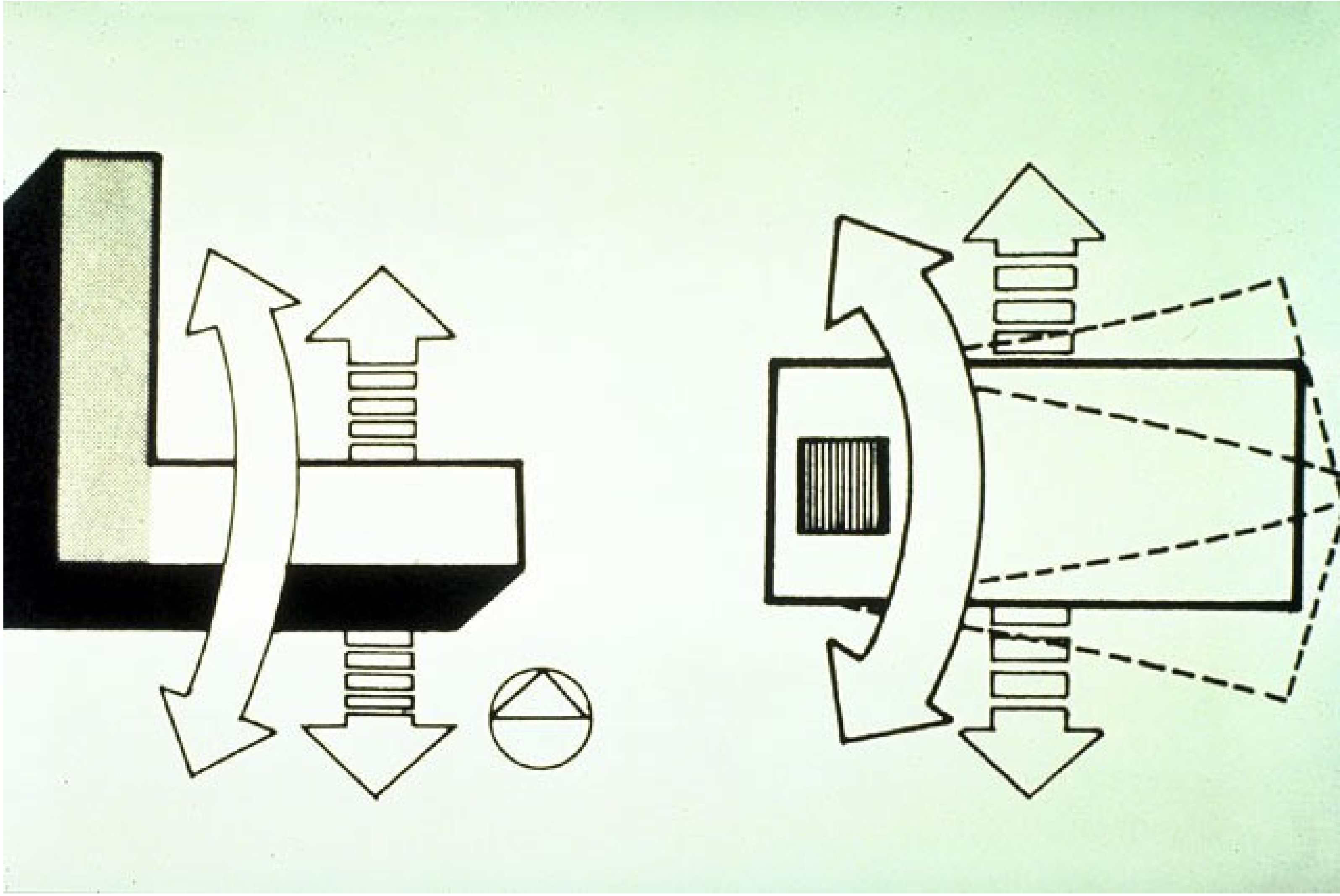




Seismic Vulnerability of Buildings

- Buildings with irregularities attract higher deformations during earthquakes, and hence are vulnerable.
- Lack of proper seismic design and detailing practices result in brittle behaviour.
- Interference of non-structural elements may cause unexpected deficiencies in seismic capacities.

Effect of Torsion



Effect of Torsion

Effect of Torsion

Effect of Vertical Discontinuity

Effect of Vertical Discontinuity

Effect of Vertical Irregularity

Effect of Vertical Irregularity

Effect of Vertical Irregularity

Effect of Soft Storey

Effect of Soft Storey

Effect of Soft Storey

Lack of Seismic Design and Detailing

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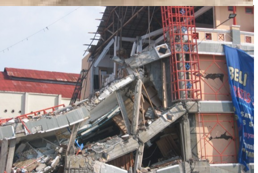





Lack of Seismic Design and Detailing

Lack of Seismic Design and Detailing

Lack of Seismic Design and Detailing

Lack of Concrete Confinement

Short Column Effect

Short Column Effect

Damage to Bridge Infrastructure

1995 Kobe E.Q. in Japan

1999 Kocaeli E.Q. in Turkey

1994 Northridge E.Q.







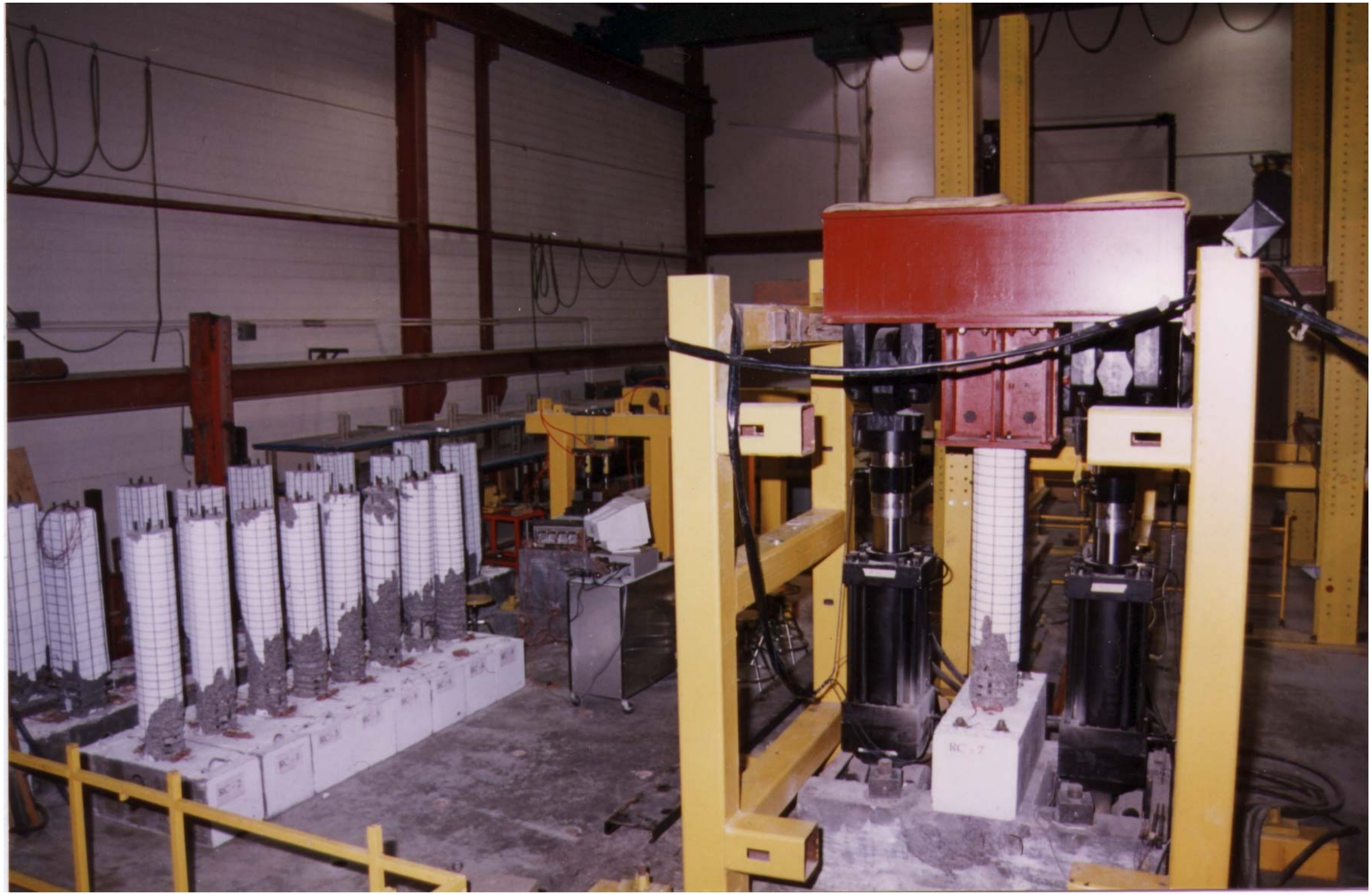
May 12, 2008 Wenchuan Earthquake in China

2010 Earthquake in Chile

2010 Earthquake in Chile

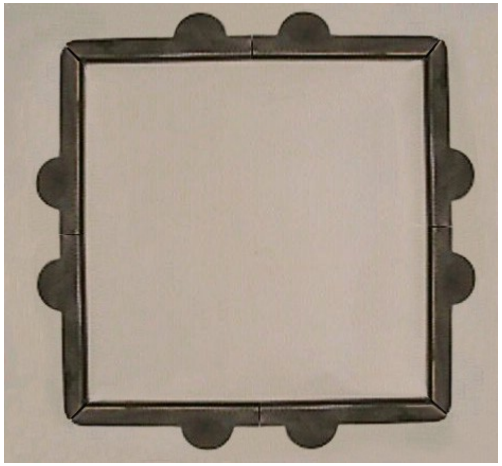
Earthquake Engineering Research

Structures Laboratory

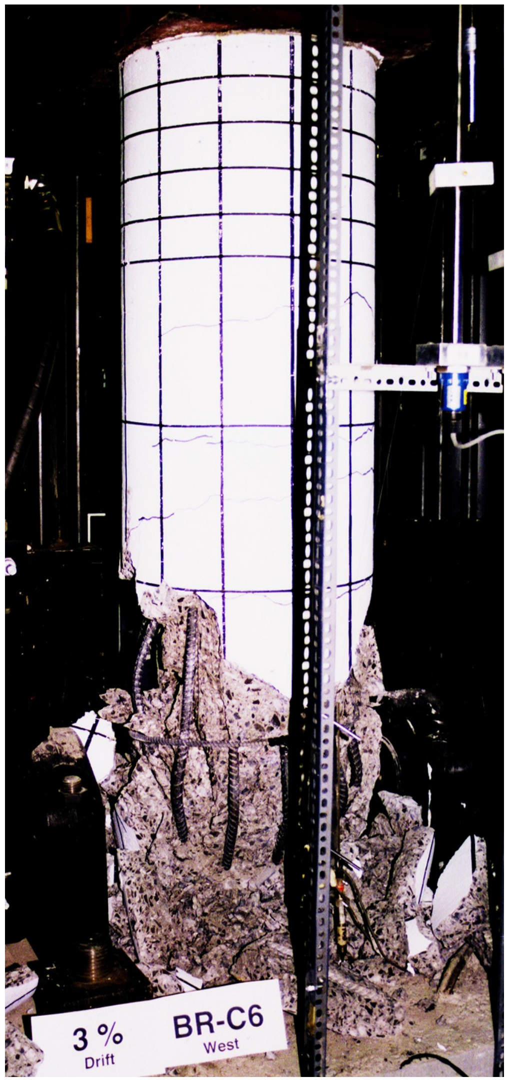


Research on Seismic Retrofit

RetroBelt Seismic Retrofit Technique

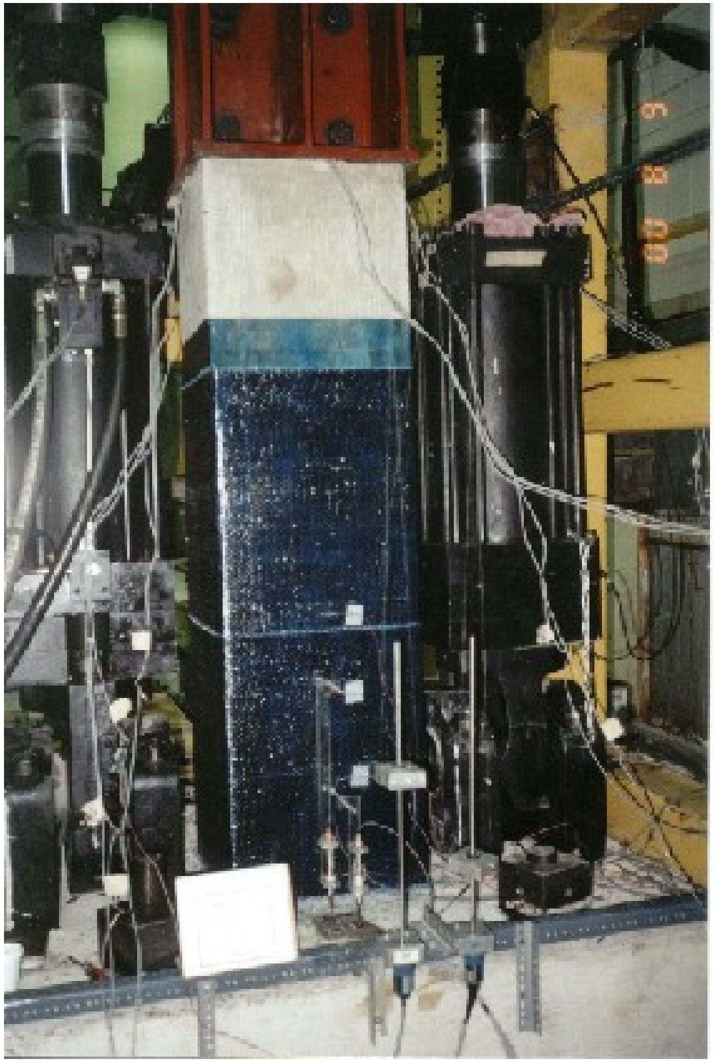


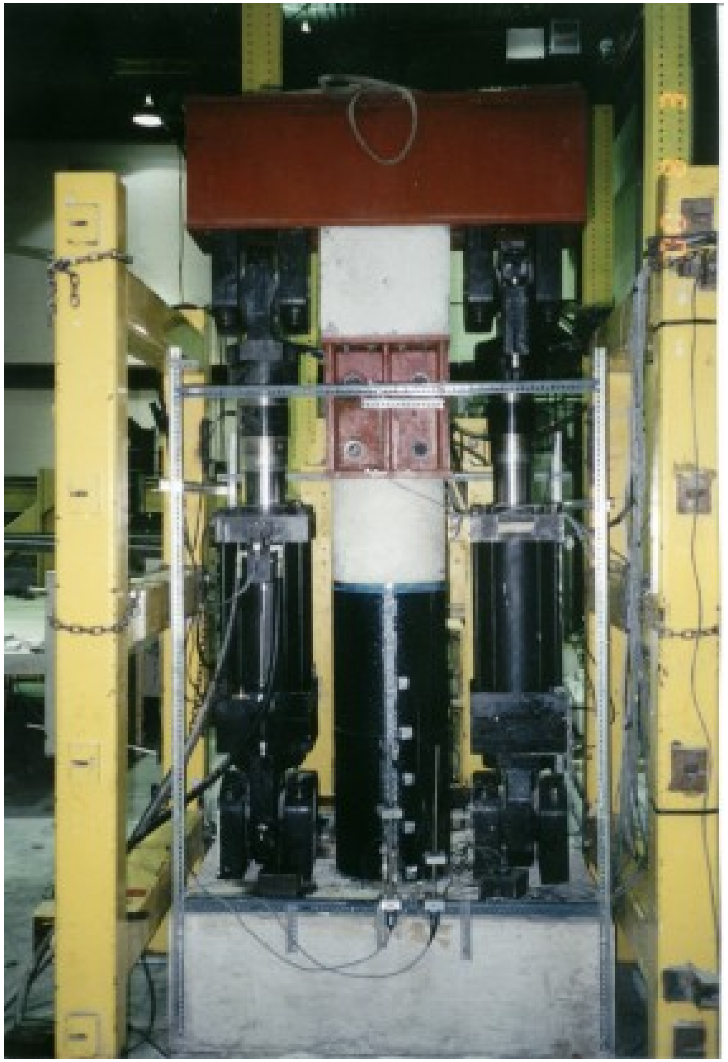
RetroBelt Seismic Retrofit Technique



FRP Jacketing

FRP Jacketing





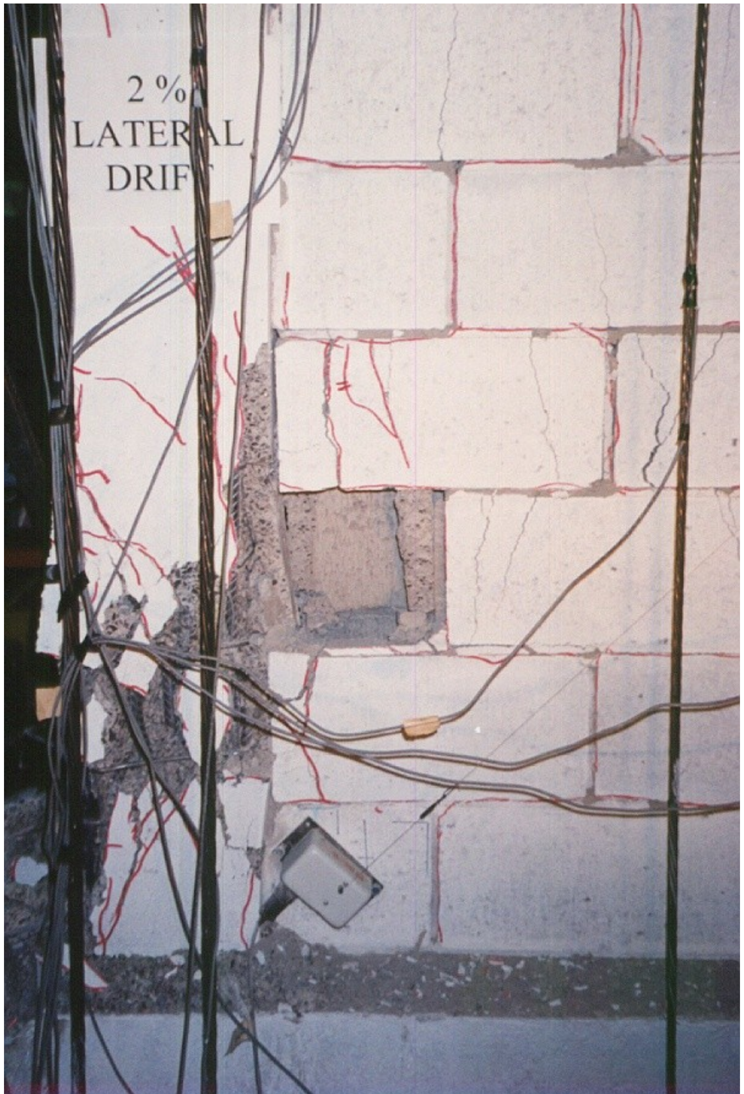


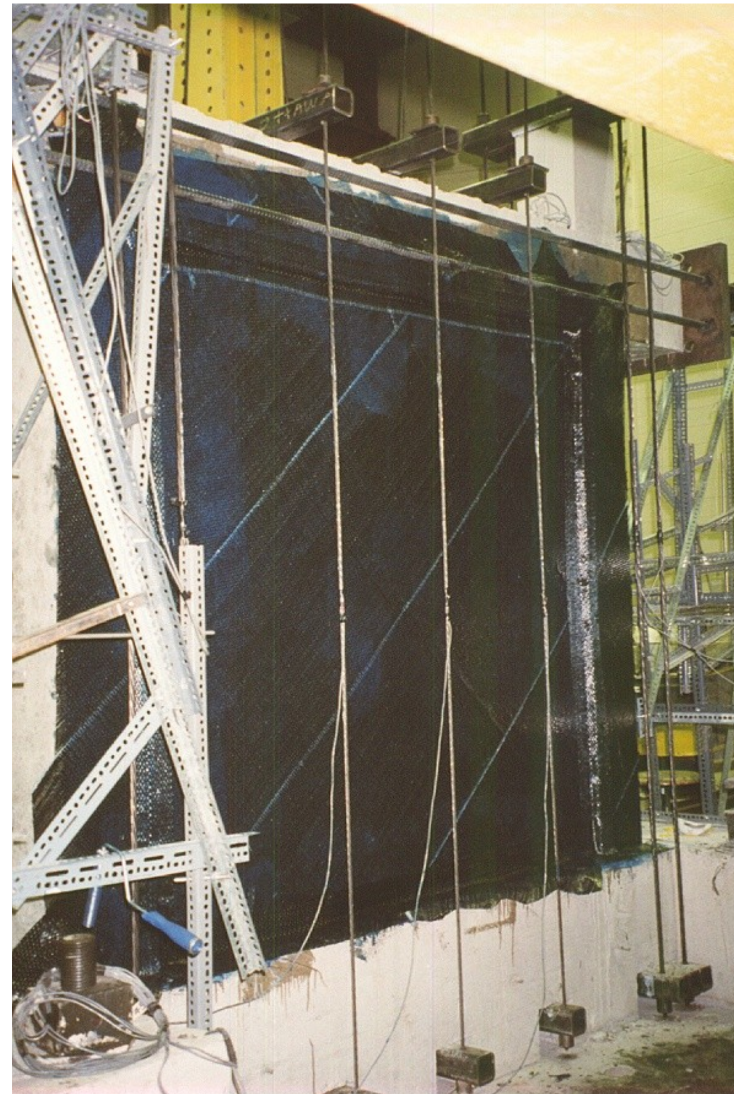




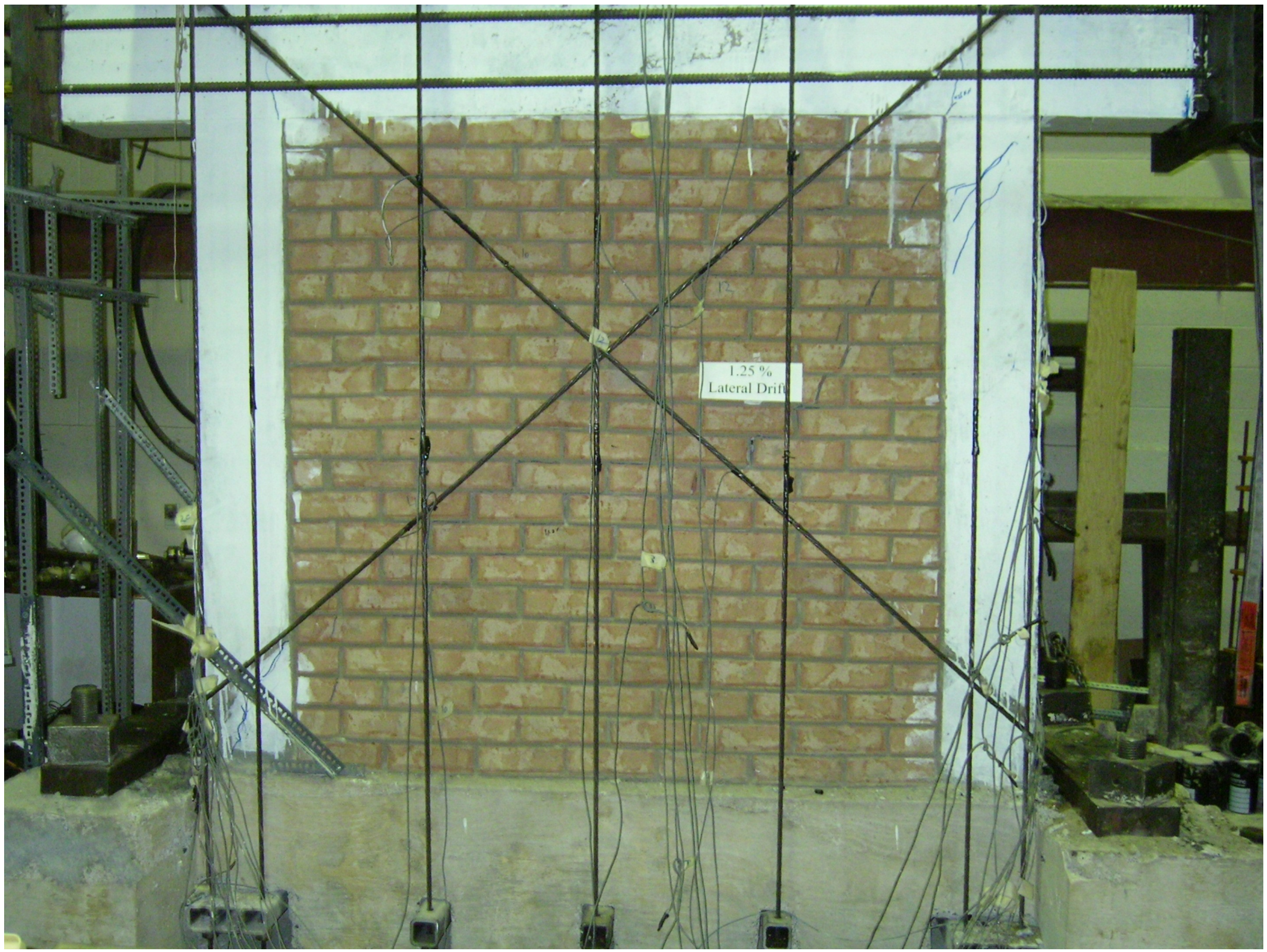
Lateral Bracing as Seismic Retrofit Technology

Lateral Bracing as Seismic Retrofit Technology



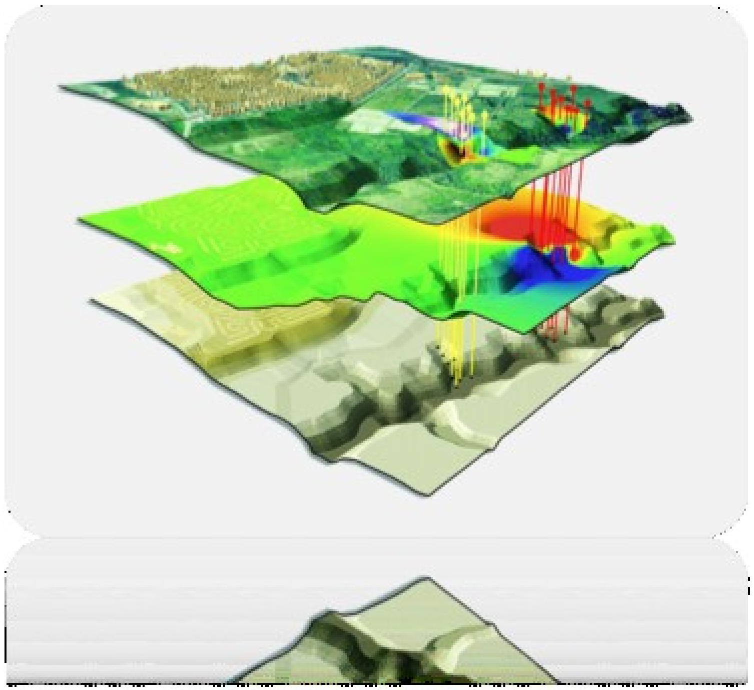


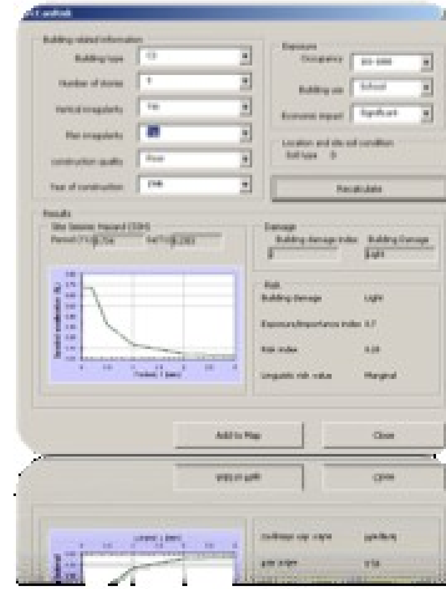
Lateral Bracing as Seismic Retrofit Technology



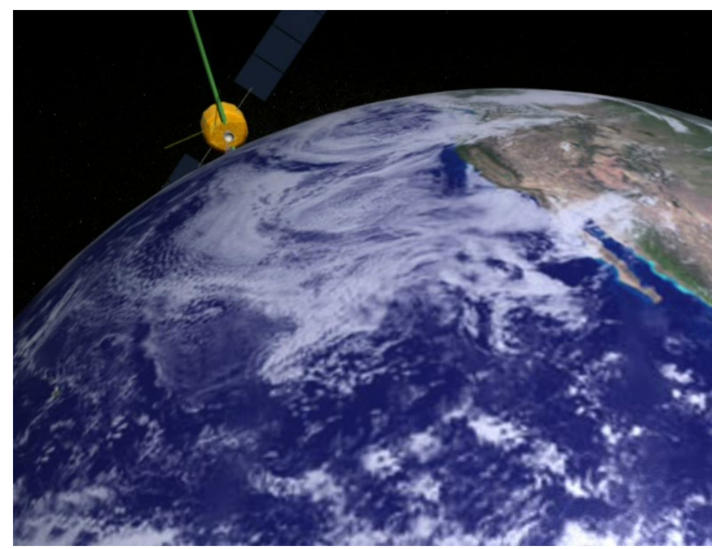
Lateral Bracing as Seismic Retrofit Technology

Seismic Risk Assessment

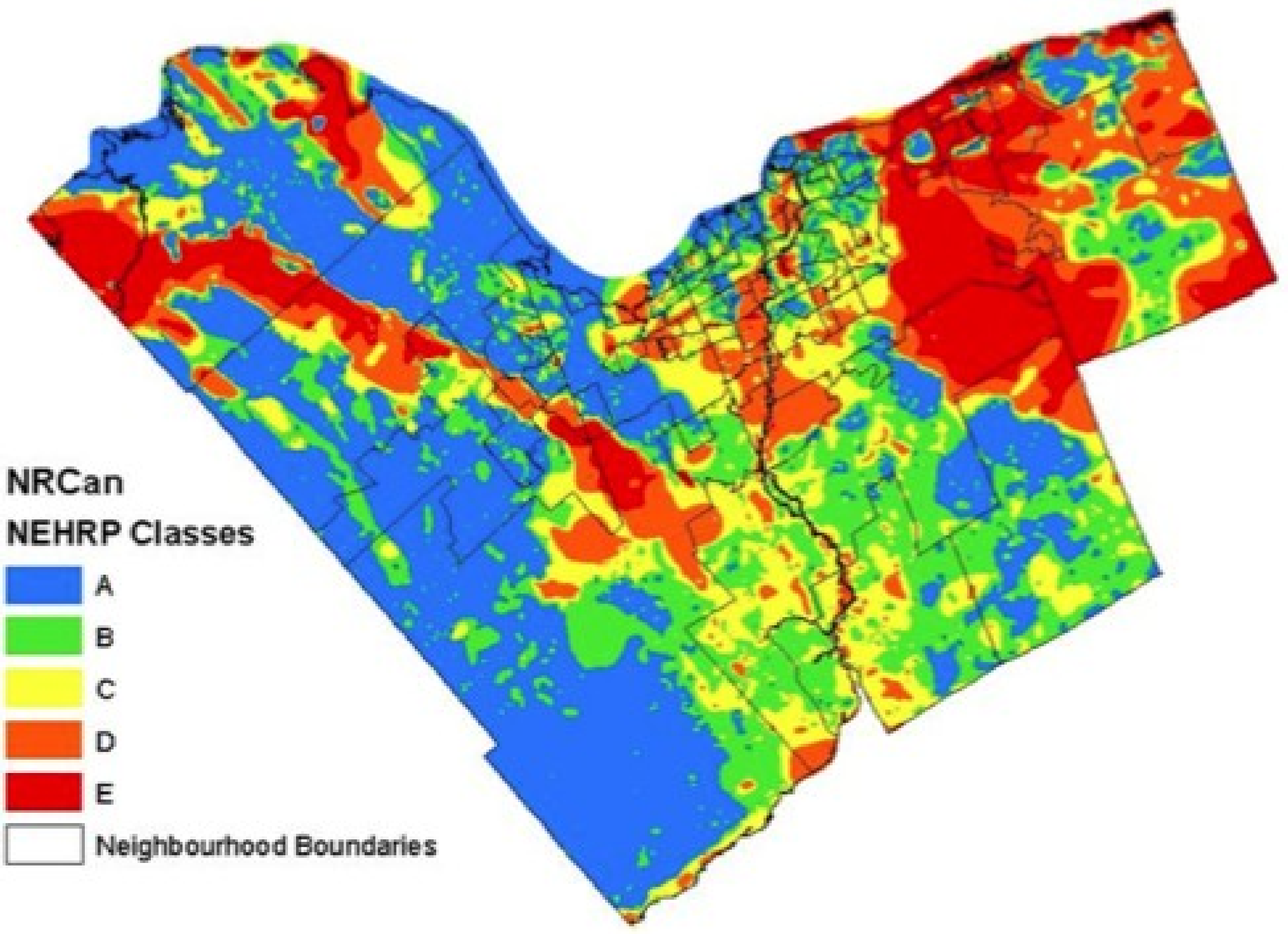




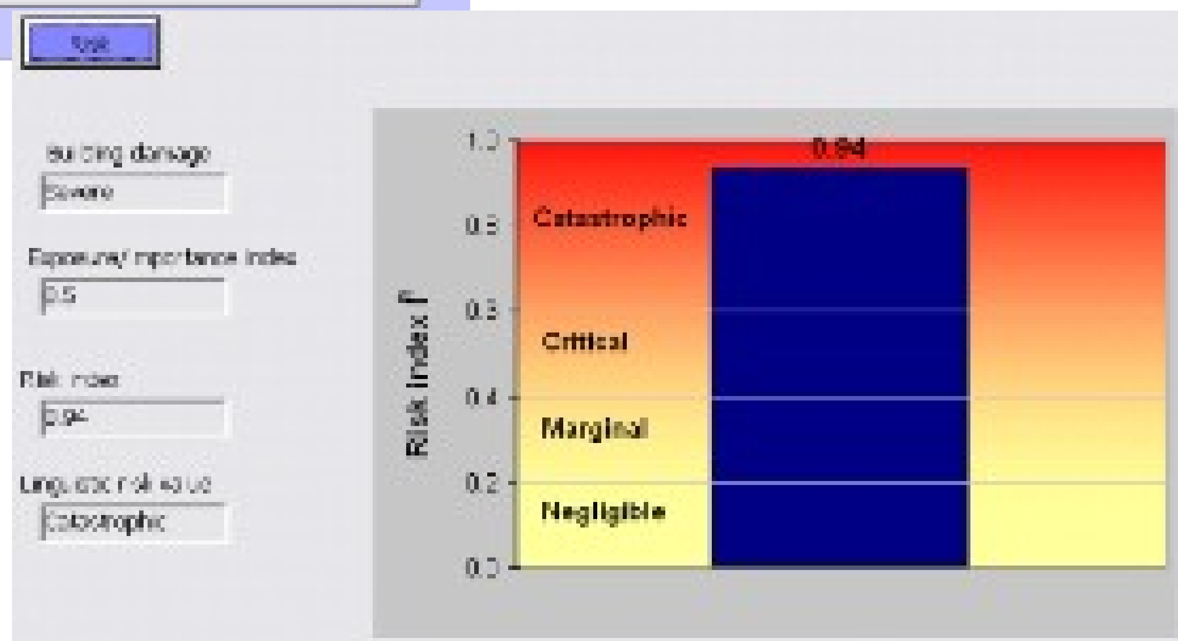
arcCanRisk



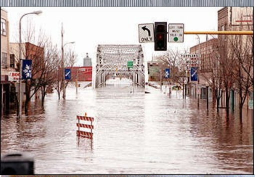
Microzonation for Ottawa




Tier 1 Evaluation
Good


Catastrophic
Critical
Marginal
Negligible
0.94
Risk Index

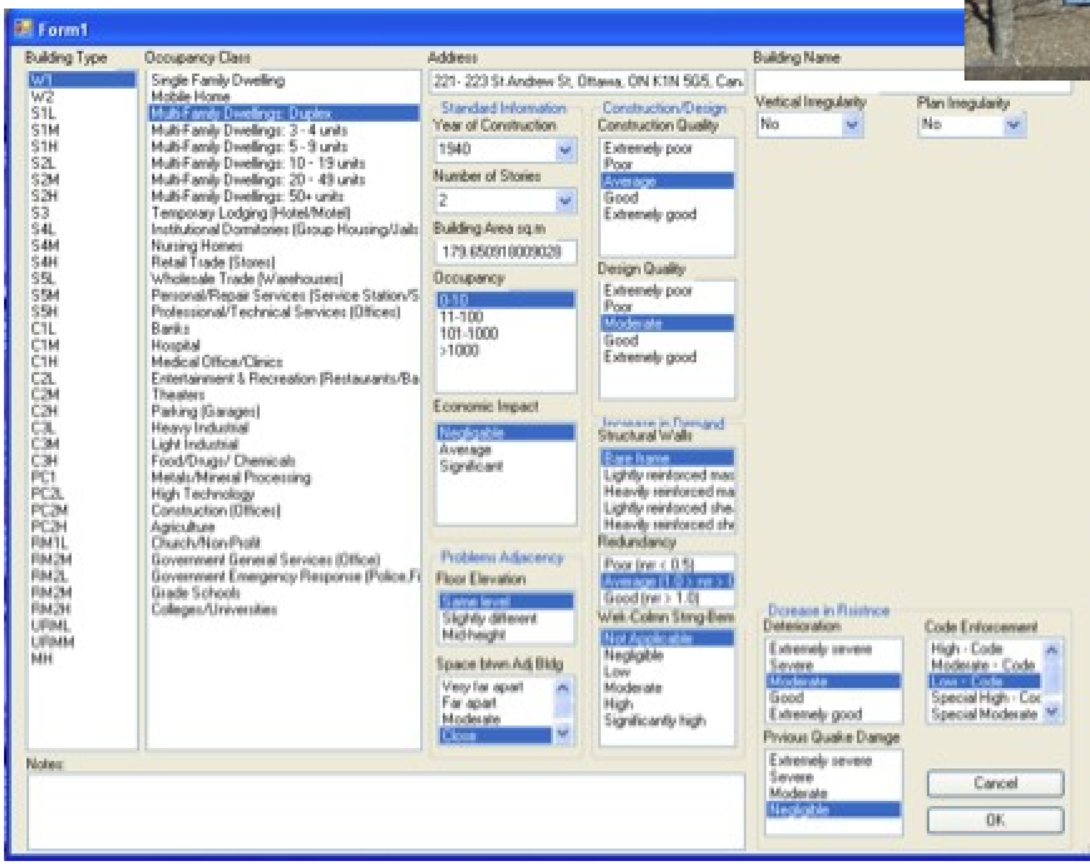






arcCanRisk

Data Collection for Ottawa



Data Collection for Ottawa

Blast Risk

Blast Risk

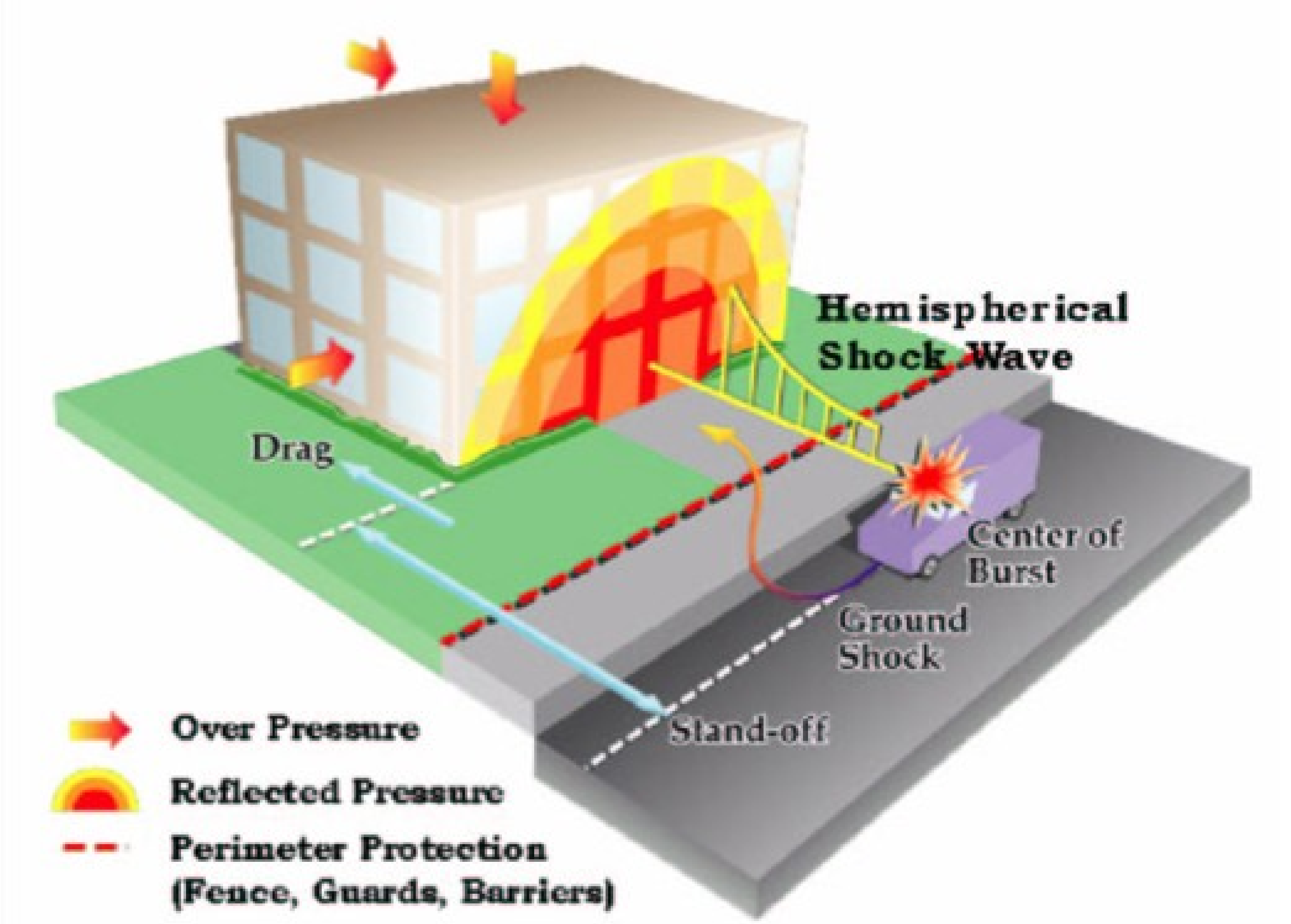
Bomb blasts generate:

- ❑ **Shock Waves**
- ❑ **Flying debris (fragmentation)**
- ❑ **Fireball effect**

Blast Hazard

- Car Bombs Pose High Hazard
- Parcel Bombs Pose Low Hazard
- The primary parameters that define blast hazard are **charge weight** and **standoff distance**

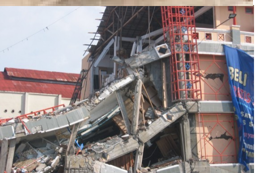
Shock Waves


Hemispherical
Shock Wave
Drag
Center of
Burst
Ground
Shock
Stand-off
Over Pressure
Reflected Pressure
Perimeter Protection
(Fence, Guards, Barriers)

To Reduce The Effects of Shock Waves…

An important step is to reduce deformation and/or force demands in structural and non-structural building components. This is achieved through;

- **proper selection of structural layout and/or structural system**
- **providing sufficient protection by increasing protected standoff distances against external attacks, and providing security and controlled access against internal attacks**

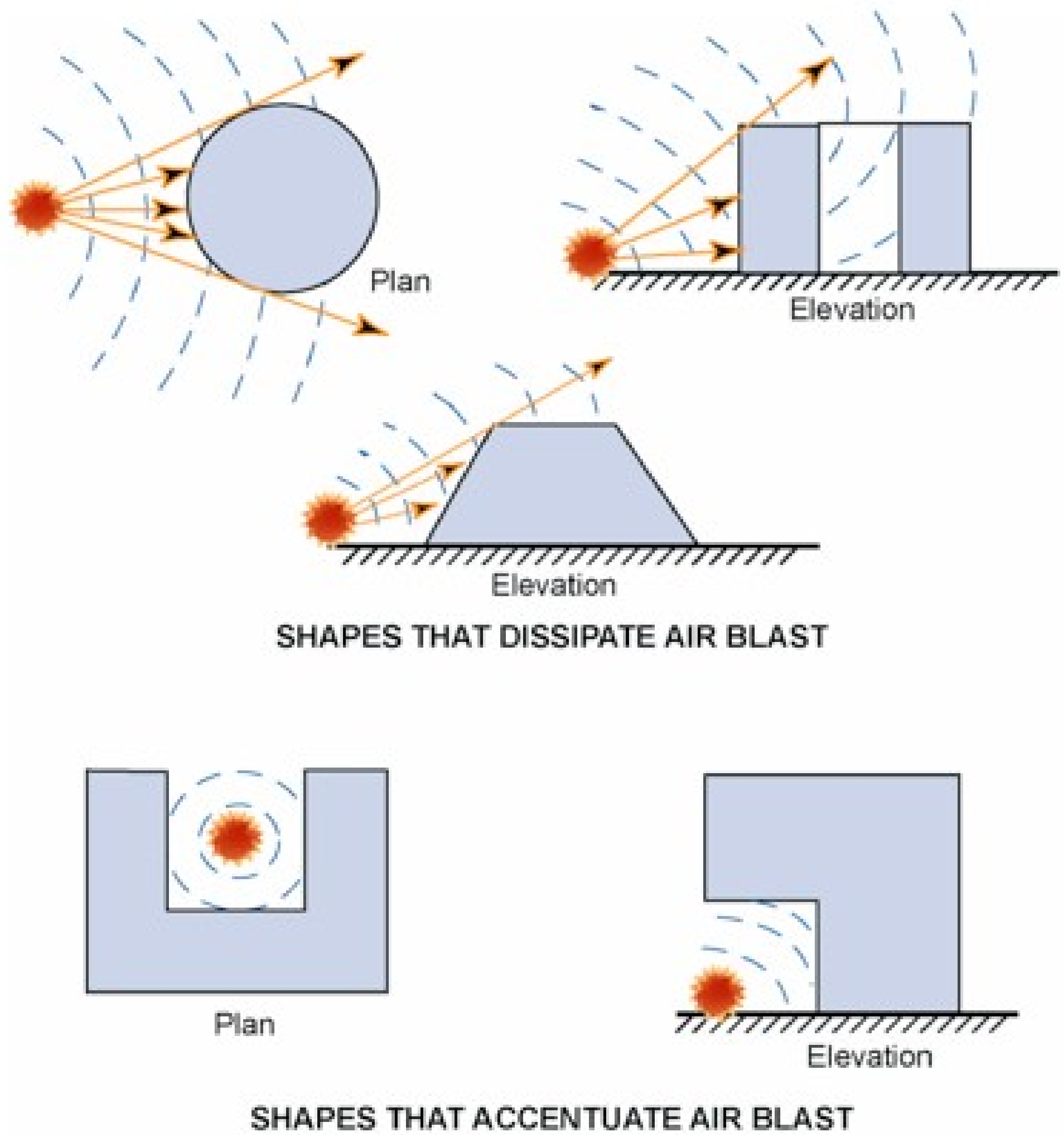





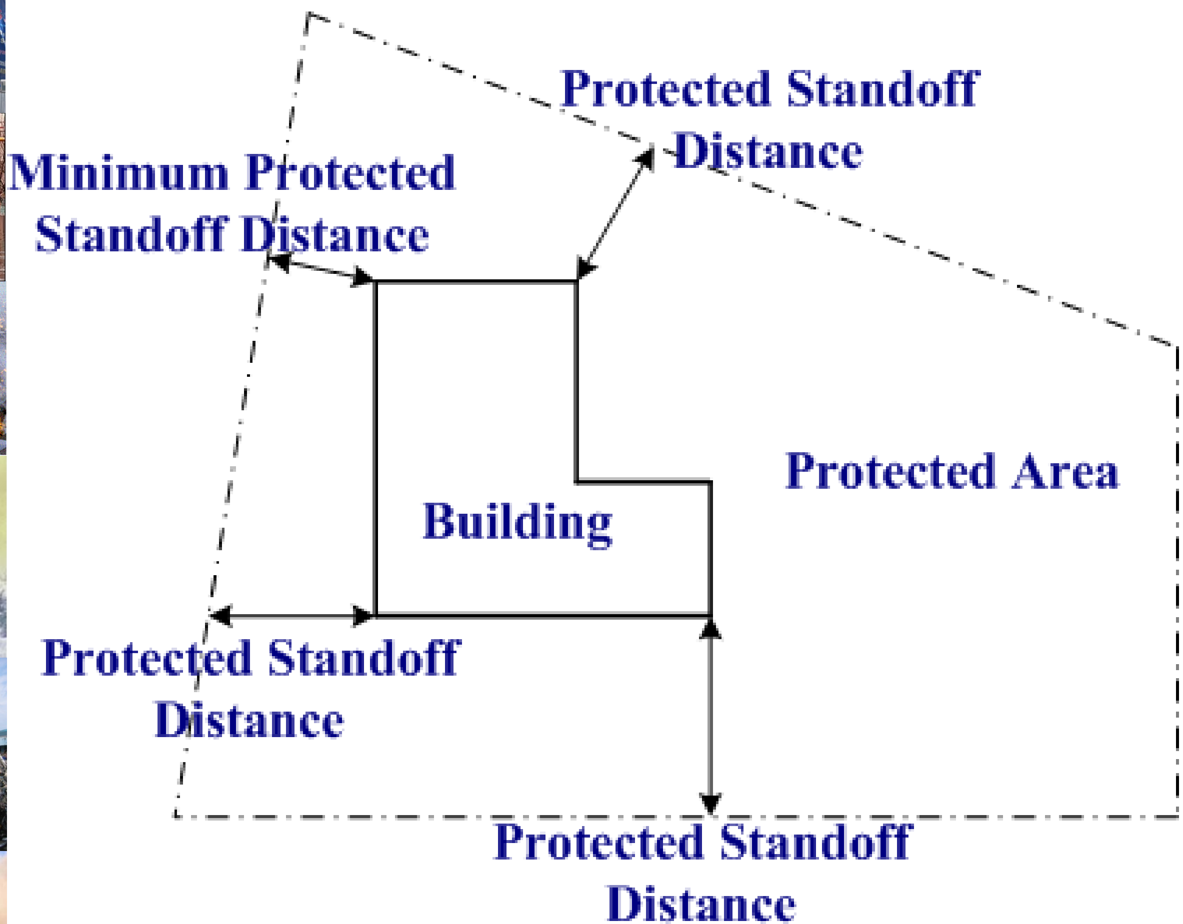

Selection of Building Layout

The building shape and layout should be selected to minimize the effects of blast loading. Re-entrant corners and overhangs are likely to trap shock wave and amplify the effect of blast. The reflected pressure on the surface of a circular building is less intense than on a flat building. When curved surfaces are used, convex shapes are preferred over concave shapes.

Selection of Building Layout



Standoff Distance



Standoff Distance

Construction Type	Minimum Protected Standoff Distance in Meters		
	Level of Protection		
	Low	Medium	High
Monolithic reinforced concrete construction	8	10	30
Precast concrete construction	16	30	50
Steel construction with rigid frames	8.0	10	30
Lightweight steel framed structures (i.e., Butler style buildings, etc)	16	30	50
Reinforced masonry walls with steel or reinforced concrete frame	8	10	30
Unreinforced masonry bearing walls	16	30	87
Timber frame construction	28	36	108

Selection of Structural Type and Material

- Cast-in-place reinforced concrete is the structural system preferred for blast-resistant construction. This is the material and structural type used for military bunkers. The military has performed extensive research and testing of its performance

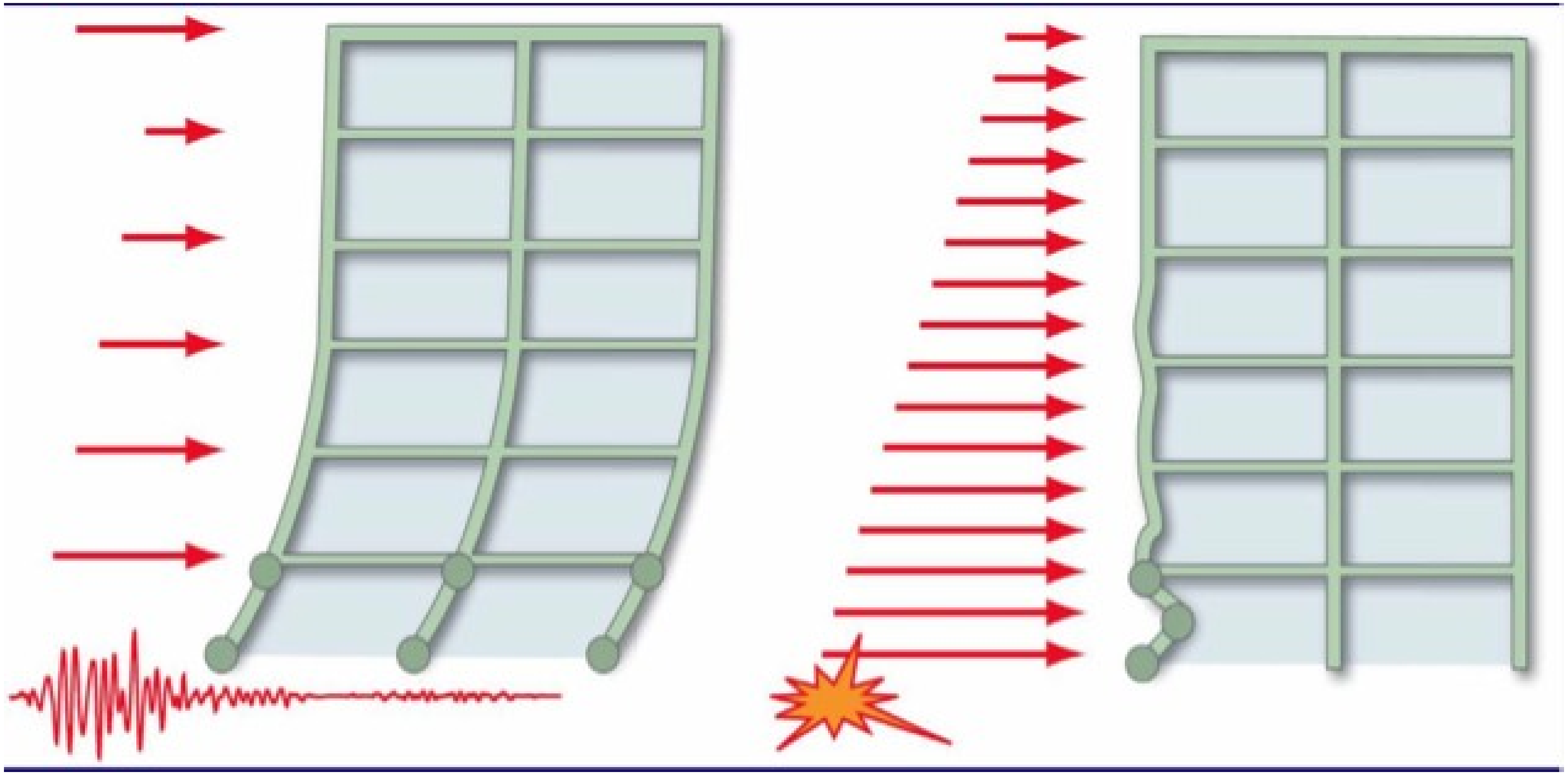
Selection of Structural Type and Material

- Lightweight construction is unsuitable for providing air-blast resistance. For example, a building with steel deck roof construction will have little air-blast resistance. The performance of a conventional steel frame with concrete fill over metal deck depends on the connection details.

Selection of Structural Type and Material

- Unreinforced masonry provides some resistance at far standoff distances due to its mass. However, it does not posses any ductility, and fail catastrophically beyond the elastic limit.
- Reinforced masonry may show improved behaviour. However, it does not allow sufficient continuity, ductility and redundancy

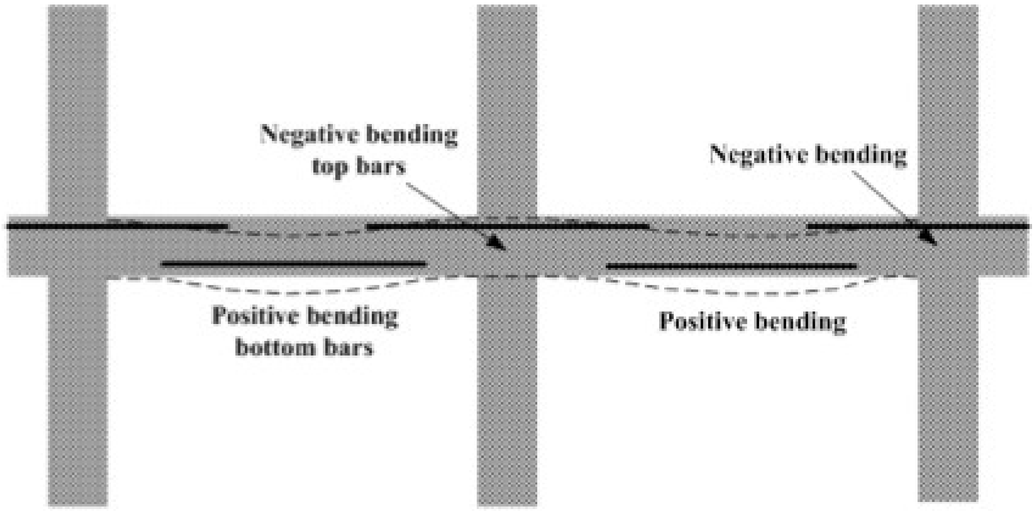
Seismic Versus Blast Loading

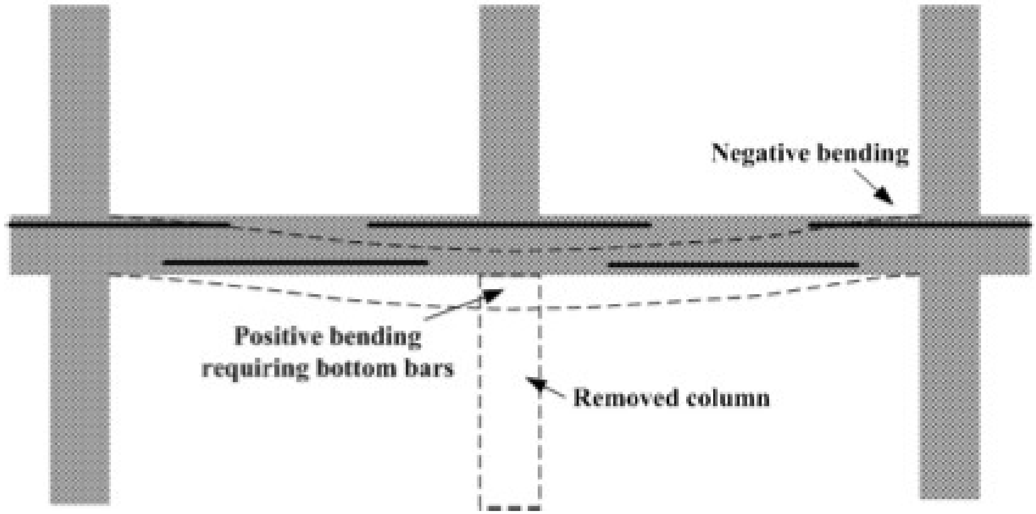


Structural Damage Due to Blast

- Element Damage (near the exposed surface)
- Progressive collapse
- Global response (not likely to cause damage unless very light structure)

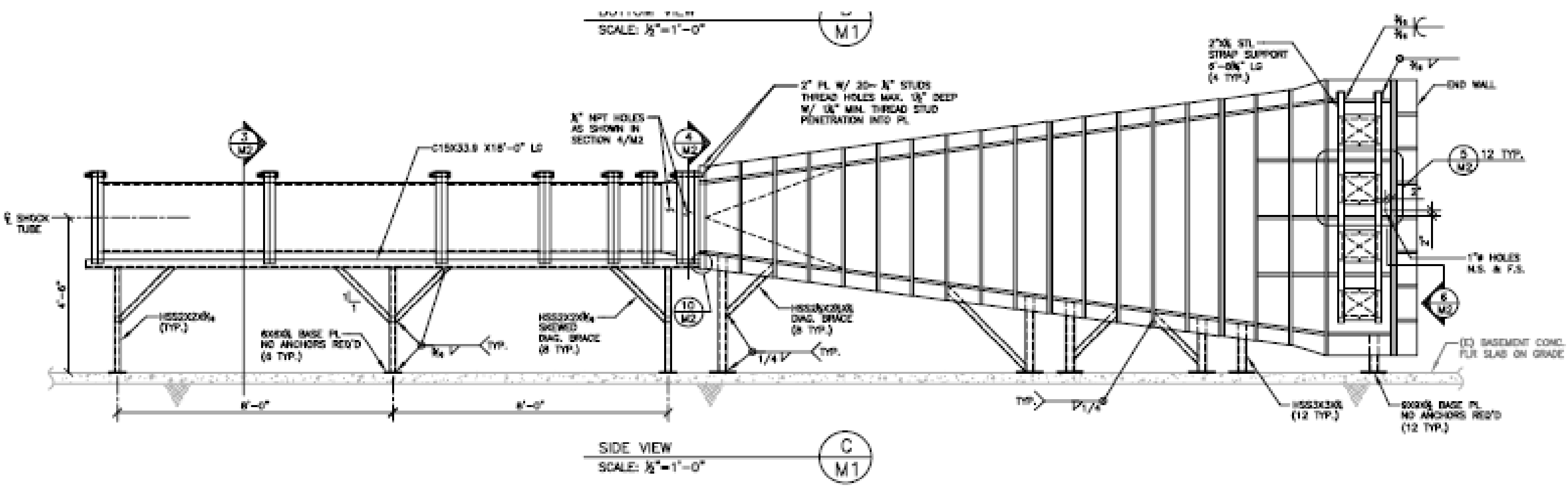
Progressive Collapse





Progressive Collapse

Research @ uOttawa



Shock Tube

Capacity:

Reflected Pressure : 10 psi (15 psi)

Duration: 40 msec (50 msec)

Service Life: 300 shots/year for 20 years

Geometry:

Length: Approx. 11 m

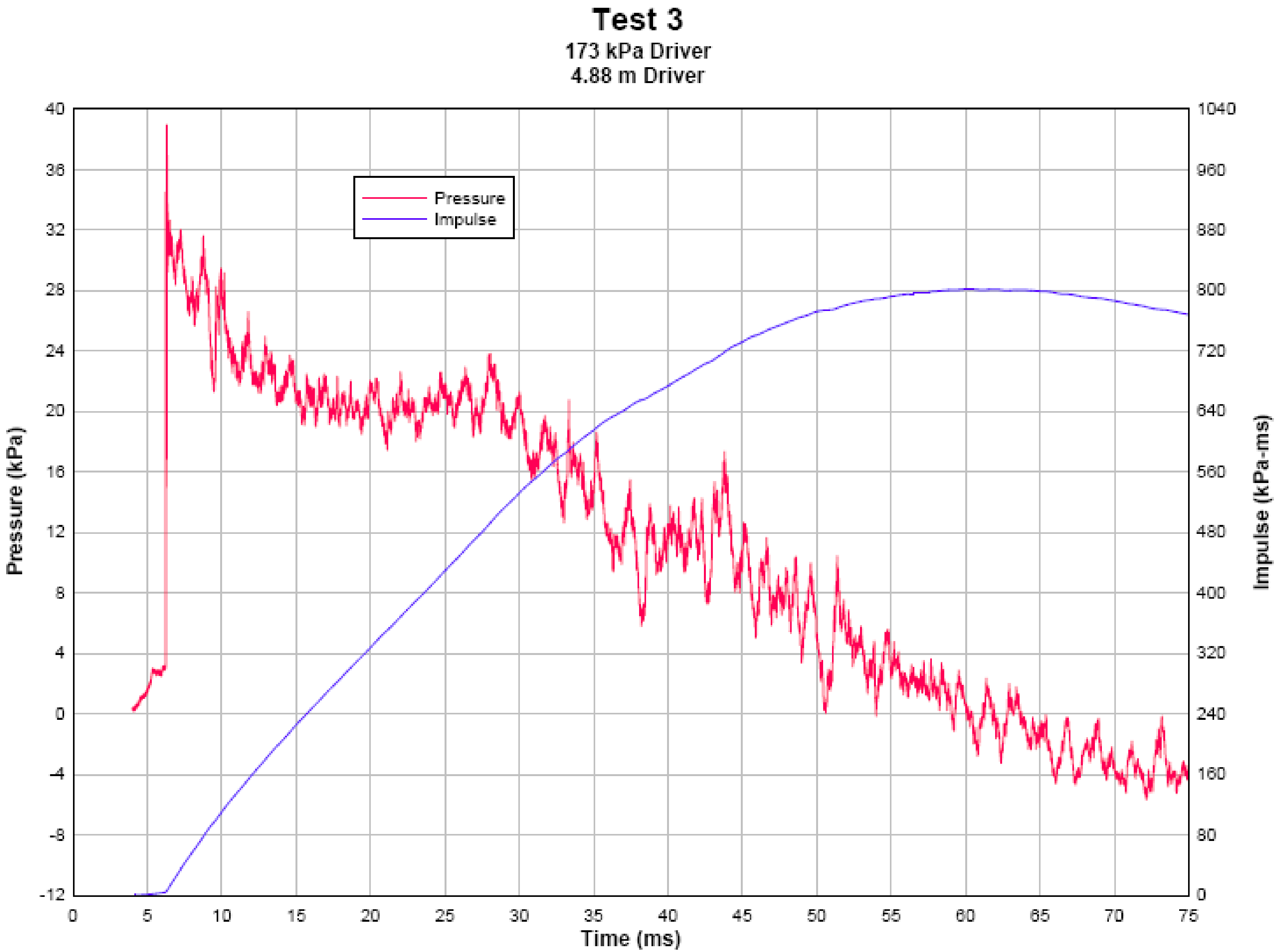
Spool Diameter: 0.6 m

Test Area: 2 m x 2 m

Shock Tube

Shock Tube

Example Shock Wave



Shock Tube Testing - Slab

Shock Tube Testing - Timber

Shock Tube Testing - Columns

Shock Tube Testing - Columns

Conclusions…

Questions or Comments?