Development and Applications of Seismic Base Isolation for Bridges in Quebec

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Development and applications of SBI in Quebec

Development of SBI

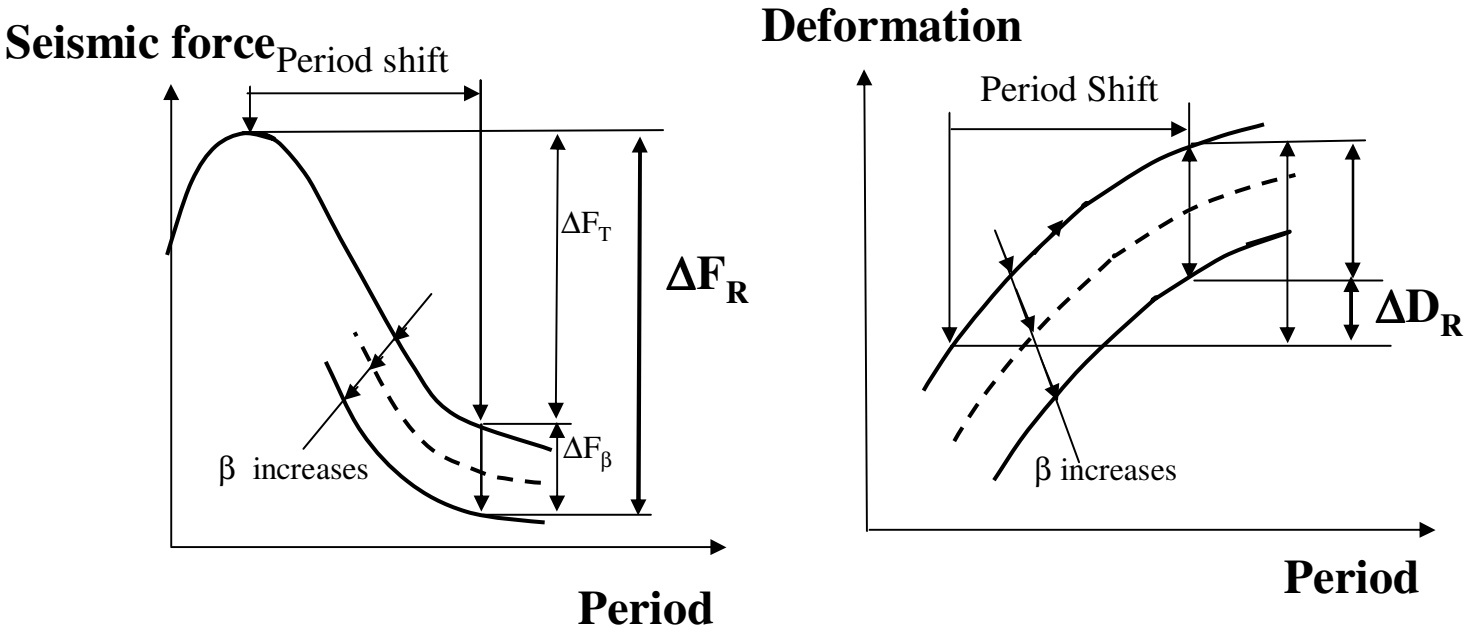
- SBI Basics
- Historic Overview /Context of the S6

Applications in Quebec

- Particularities
- Used systems / main features
- 2 examples of application

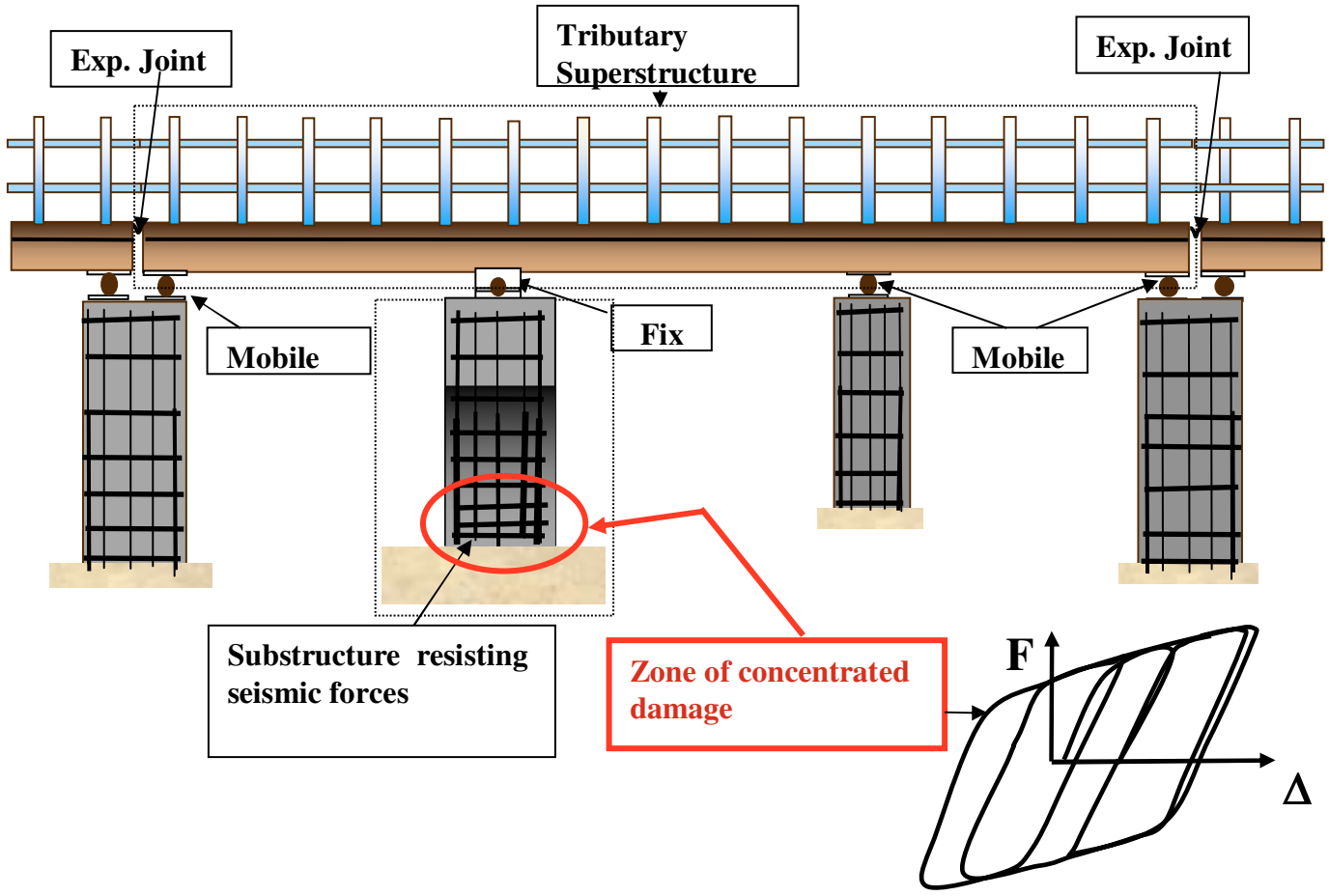
Some S6 Issues

SBI basics

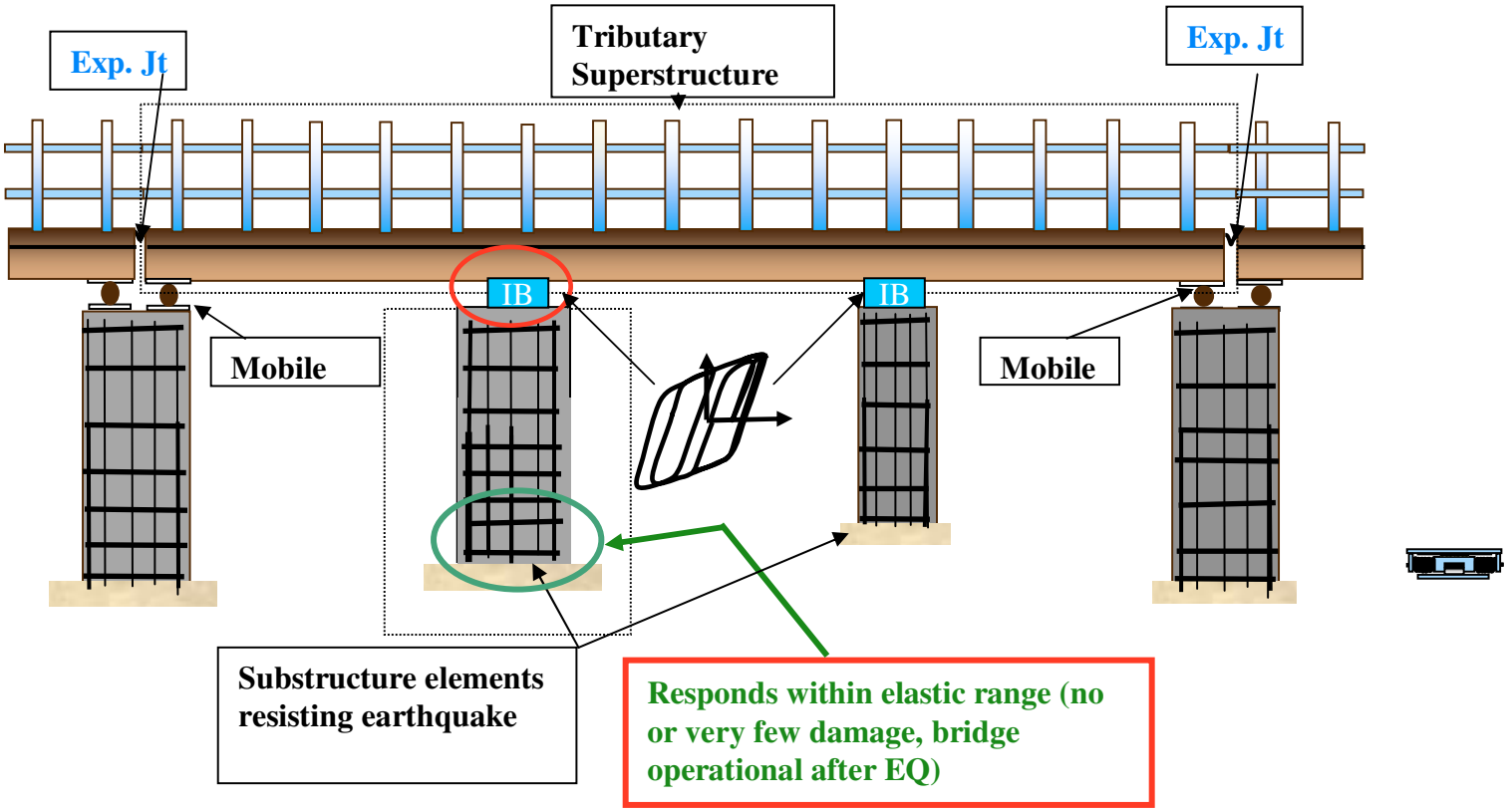


- **Shift the fundamental period from dominant earthquake input motion to reduce seismic forces.**
- **Control increased deformation by incorporating a high damping mechanism**

Fixed base design (conventional)



Application of SBI for bridges



Development of SBI in Quebec

- Historic overview
  - 1st applications of SBI:
    - 1970 :Italy, 1983: US, 1991 : B.C., Canada
  - 1994- 1997 Research Project @ EPM
    - Ph.D. Thesis, EPM (A. Filiatrault & G. Bondonnet)
    - Collaboration: Z-Tech, MTQ, EPM, NRC
    - Concept of an original SBIS, prototype, shake table tests, CHBDC 97, AASHTO 91, NIST 94 and other codes tests, …
  - 1997-2001: Long term tests and improvement
    - Z-Tech, MTQ, CRIQ, ETS, EPM
    - Low temperature tests, corrosion tests, elastic restrainers, generalisation to 2D
    - Implementation of design procedure
  - 2002 : First application of SBI in Quebec (Alma Bridge)

Development of SI in Quebec

- Context of the S6-00 and S6-06
  - Much Higher level of seismic forces
  - More rational seismic forces F = f (T, I, R, …)
  - Methods of analysis requirements
  - Importance factor (lifeline bridges , I = 3.0)
  - Alternative designs : Seismic Isolation
  - Specifications on the design and testing of SBI
  - Unique Spectra for all Canada (no distinction between East and West zones)

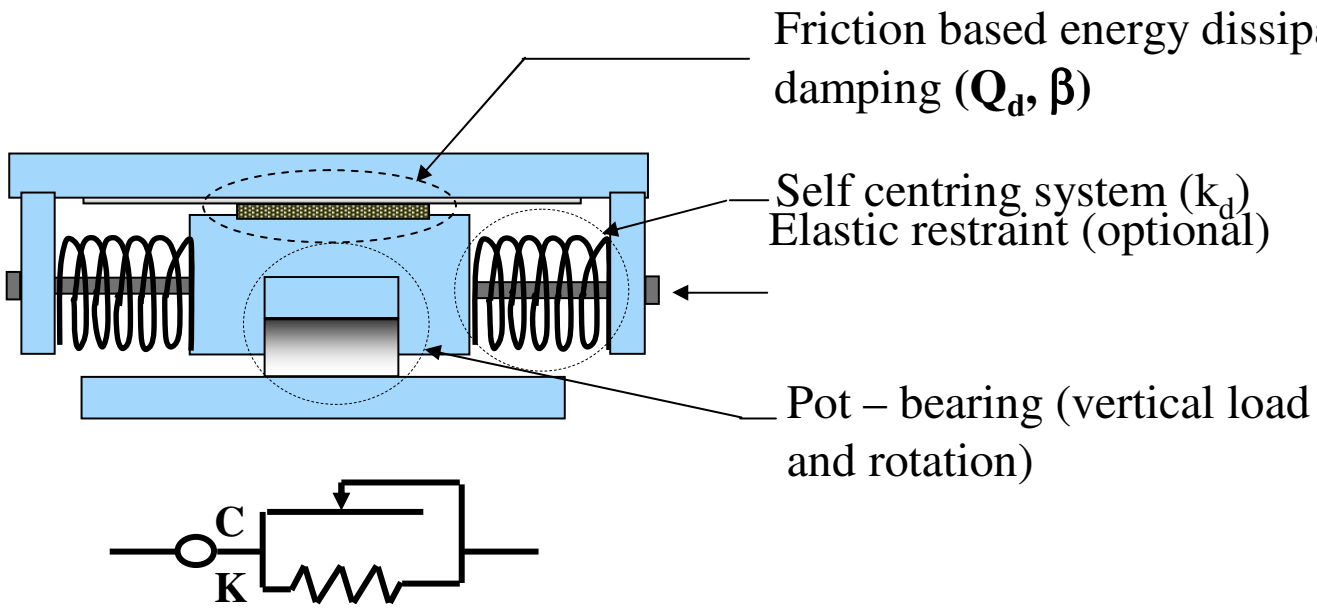
→ Boosted interest by Design Engineers

Development of SBI in Quebec

- Historic overview
  - 2001-2005: S6-00
    - Specifications of S6-00
    - 1st Application of LUD and dampers on a MTQ Bridge
    - Promotion of the technologies of BI, LUD, Dampers
    - Research by suppliers: Low temperature tests, aging effects
    - Engineers : last solution
  - 2005-2007: 2nd application : Madrid Bridge
  - 2008- 2011
    - Application of SBI becomes more common /recognised: La Tuque (2007-2009), A-25 (2008-2011) , A-30 (2009-2011), A-40 / ST-Charles (2009), ….
    - Increased Research interest: EPM, MTQ, Suppliers

Used Systems in Quebec

- Sliding SBI with a pot bearing
  - By:Goodco/Z-Tech
  - Applications: Alma Bridge (Rte 169), Madrid Bridge (A-20), La Tuque Bridge (Rte 155) (2002- 2011)

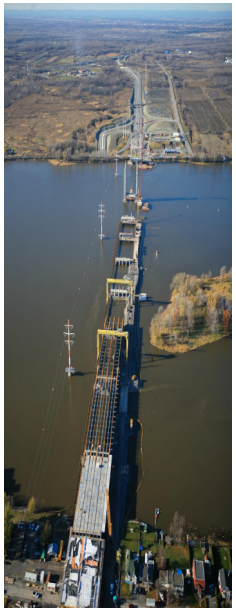


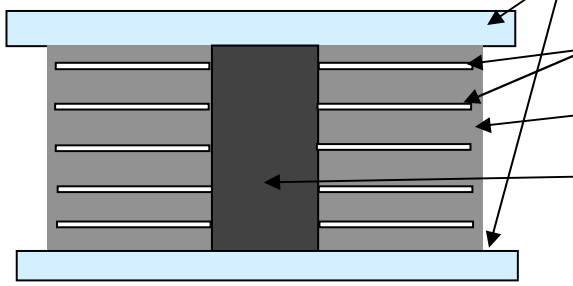
Used systems

- The "Eradiquake": Sliding SBI with disc-brg
  - By: RJ Watson
  - Applications: St-Charles (A-40) bridge (2009)

Used SBI in Quebec

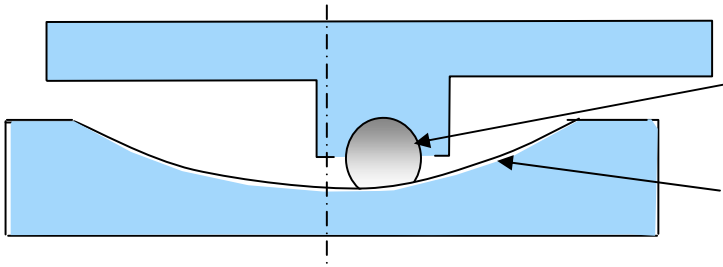
- Lead Rubber Laminated Bearing
  - By: DIS
  - Applications: A-25 Bridge (2010)





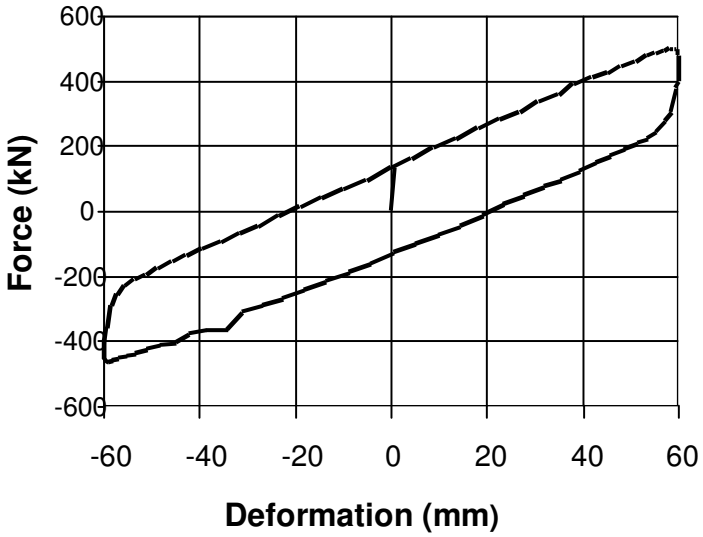
Used SBI in Québec

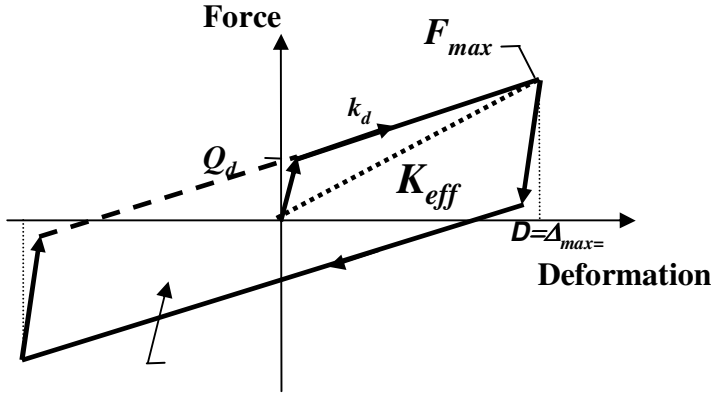
- Friction Pendulum
  - Application: A-30 (2 bridges ?)



Hysteresis Features (Exple)

- Typical behaviour





EDC : Aire sous la courbe

$\beta = EDC / (2 \pi Keff D^2)$

Experimental hysteresis cycle
(from Alma Bridge SBI tests)

Hysterisis model and eq. elastic properties

Application Exples: Alma Bridge

(1st application in Québec, 2002)

- Rte 169, Grande decharge river
- A=0.15g, v=0.15m/s
- Bridge : cont. Suiperstrure of 318m, 6 spans, steel girders, concrete participating slab
- W = 53 000 kN
- Piers:hight 10 to 40 m

Alma Bridge
(New CTN case)

- Longitudinal isolation : 4 GZT isolators @ abut + pot brgs
- Period of isolation; Te= 3.2 sec;
- D = 60mm (non linear dynamic analysis)
- K_{eff}= 21270kN/m
- β: 19.7%
- Design force @ abutment : 3564 kN = 6.6% W
- Testing : S6-00 prototype testing @ EPM

Madrid Bridge
(Seismic retrofit case)

CTN :2007-2008

- A-20 S, Nicolet river
- A=0.15g, v=0.1m/s, I=3 (S6-00)
- Bridge: 4 spans, 128m total length
- 4 steel girder, concrete slab
- W = 15500 kN
- Piers with limited lateral capacity but in good state

Madrid Bridge Seismic Retrofit

- Preliminary simplified analyses (2005)
  - F = 6 to 12%W (less then piers capacity)
  - Need to isolate in both directions
- Non linear analyses: 2006
  - Used 3 pairs of artificial accelrograms (atkinson) developped for east coast , compatible to NBC-2005 calibrated to fit the S6-00 spectra (M=7 à R=70km et M=6.0 à R=30 km)
  - Used Saguneay earthquake input (calibrated to A=.2g)
  - Results : Confirment and completed preliminary analyses results
  - Formulation of specs

Bridge CTN (2007-2008)

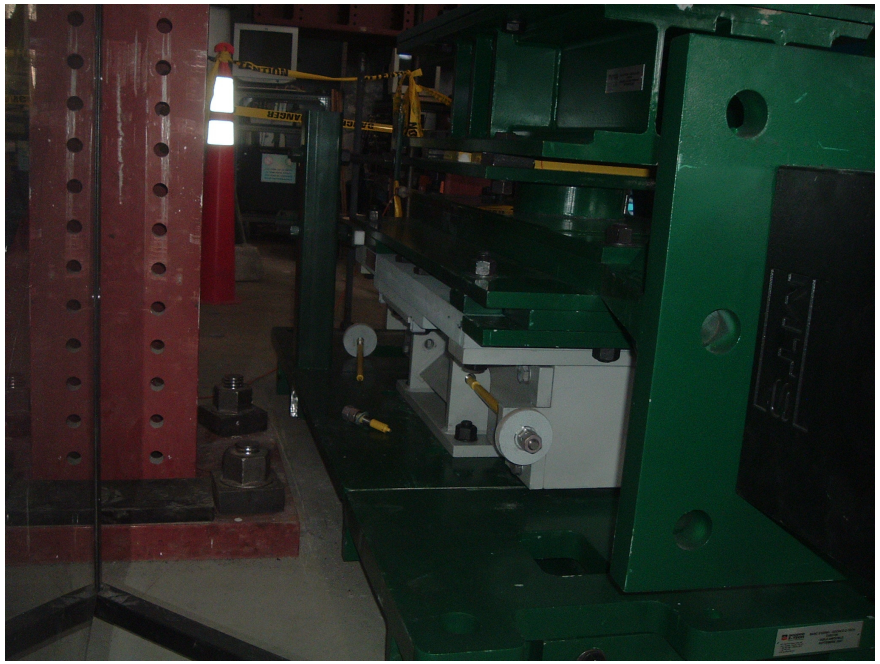
Madrid Bridge Seismic Retrofit

- Used Seismic isolation
  - Long. Direction
    - 4 GZT Isolators @ abut.
    - Dissipating energy pots @ 1 pier
    - Te= 1.87sec, β= 17.7%
    - F = 1156 kN (7.5%W), D= 50mm
  - Tranverse Direction
    - 12 GZT isolators (4 / pier)
    - Mobile pot brgs @ abutments
    - Te= 1.0, β= 36.8%
    - F =1752 kN (11.3%W), D=25mm

Madrid Bridge Rehabilitation

- Testing @ EPM
  - Prototype testing
    - Section 4.10.11 de la S6-00
    - 3 Cycles à -30°C (MTQ): **
    - 4 prototypes tested
  - QC testing
    - MCEER/ATC-49 (all 16 units)

Madrid Bridge Rehabilitation



Some S6 issues to resolve

- Adapted seismic spectra for East Canada / Uniform Hazard as NBC 2005?
- Combination of earthquake loads with temperature loads
- Restoring force requirements (twice AASHTO)
- Cold temperature testing specs
- System Qualification testing specs & QC testing specs
- Apparent conflicts to resolve

Thanks !
Questions ?