Seismic Isolation of the A30 Bridge over the St. Laurent River

CSRN Workshop on Isolated and Damped Bridges

Montreal, Canada

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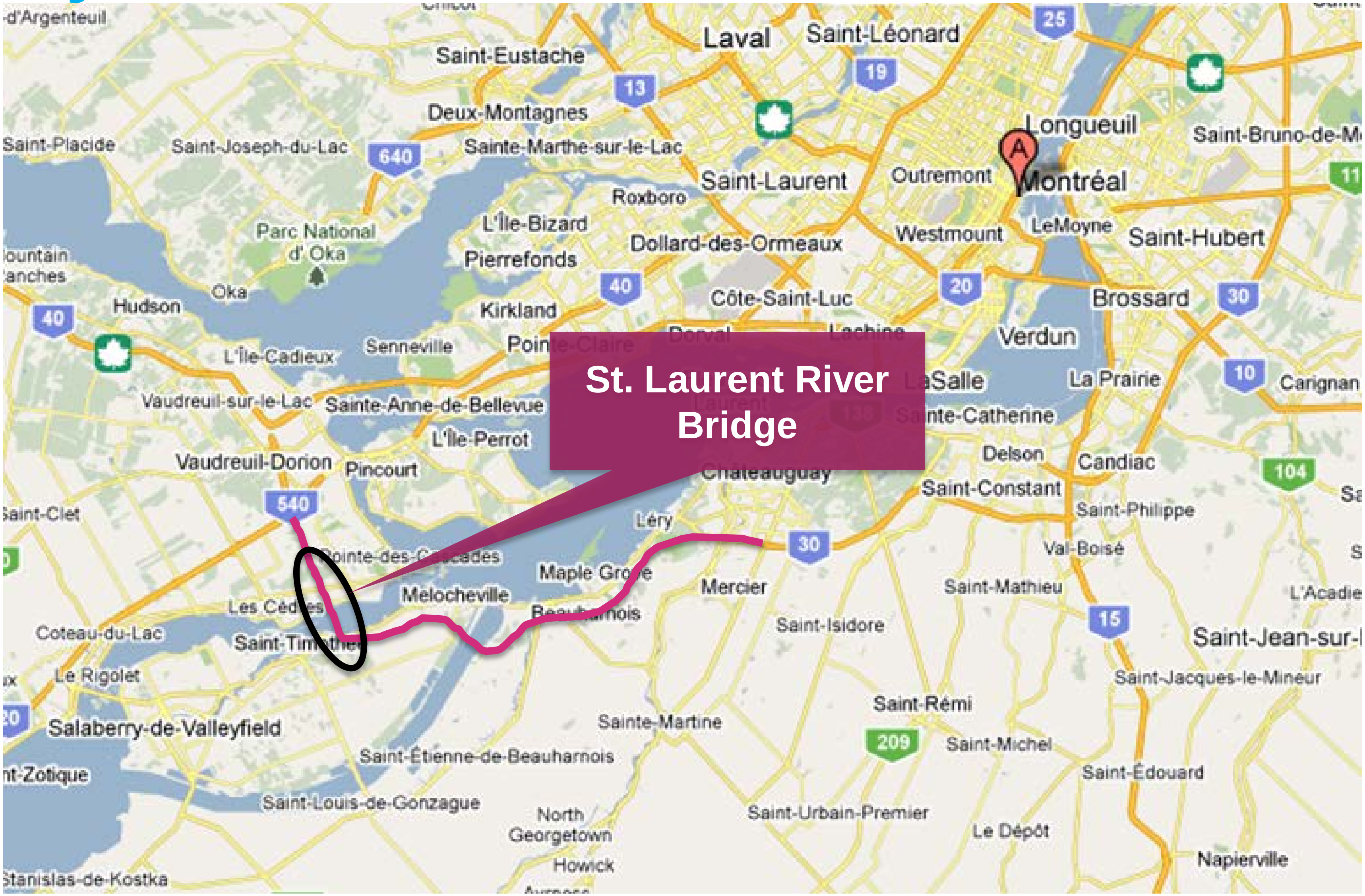
Project overview



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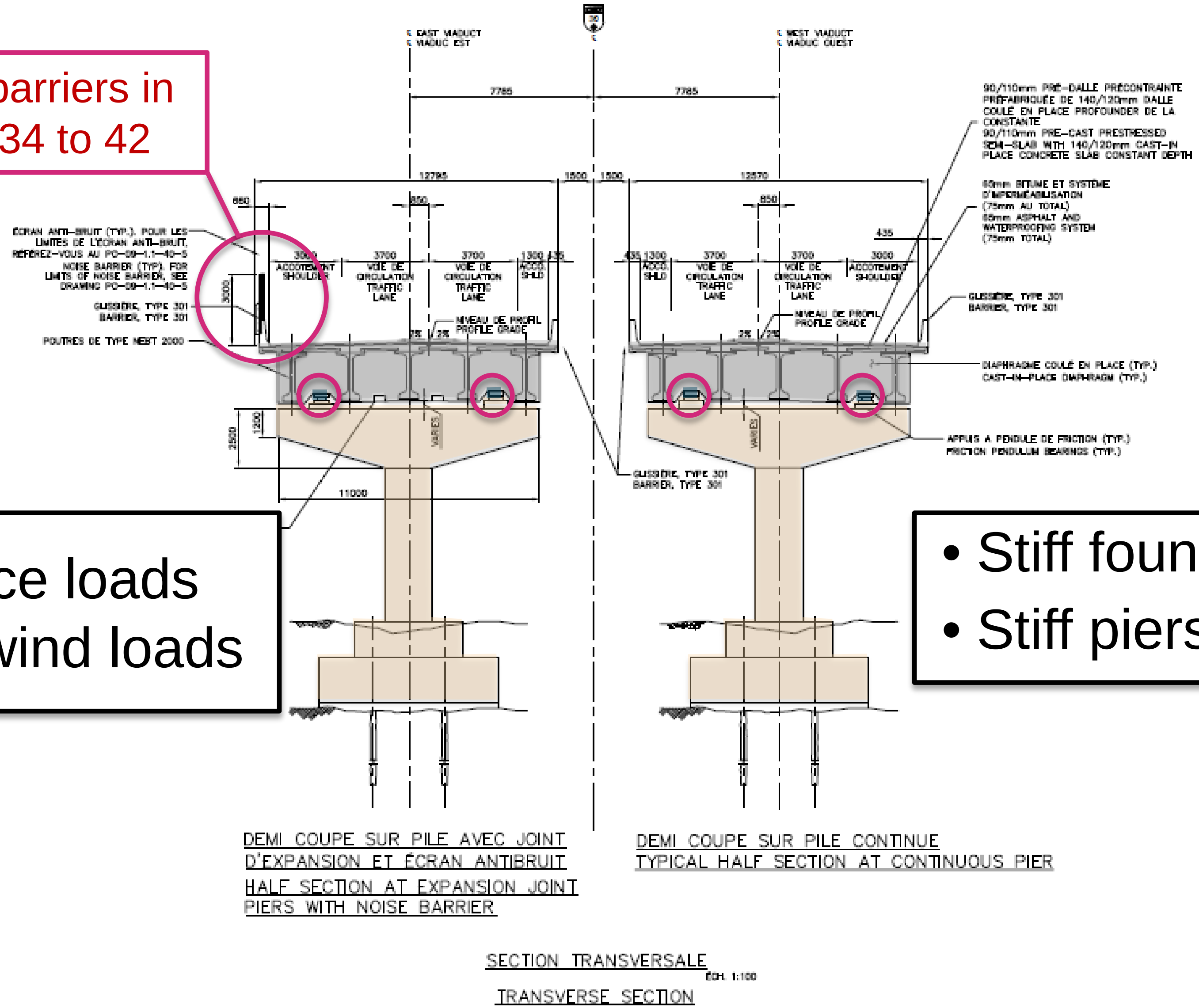
Rendering of St. Laurent River Bridge

Typical section

Noise barriers in Spans 34 to 42



- High ice loads
- High wind loads

- Stiff foundations
- Stiff piers

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Completed piers – north end

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Completed piers – south end

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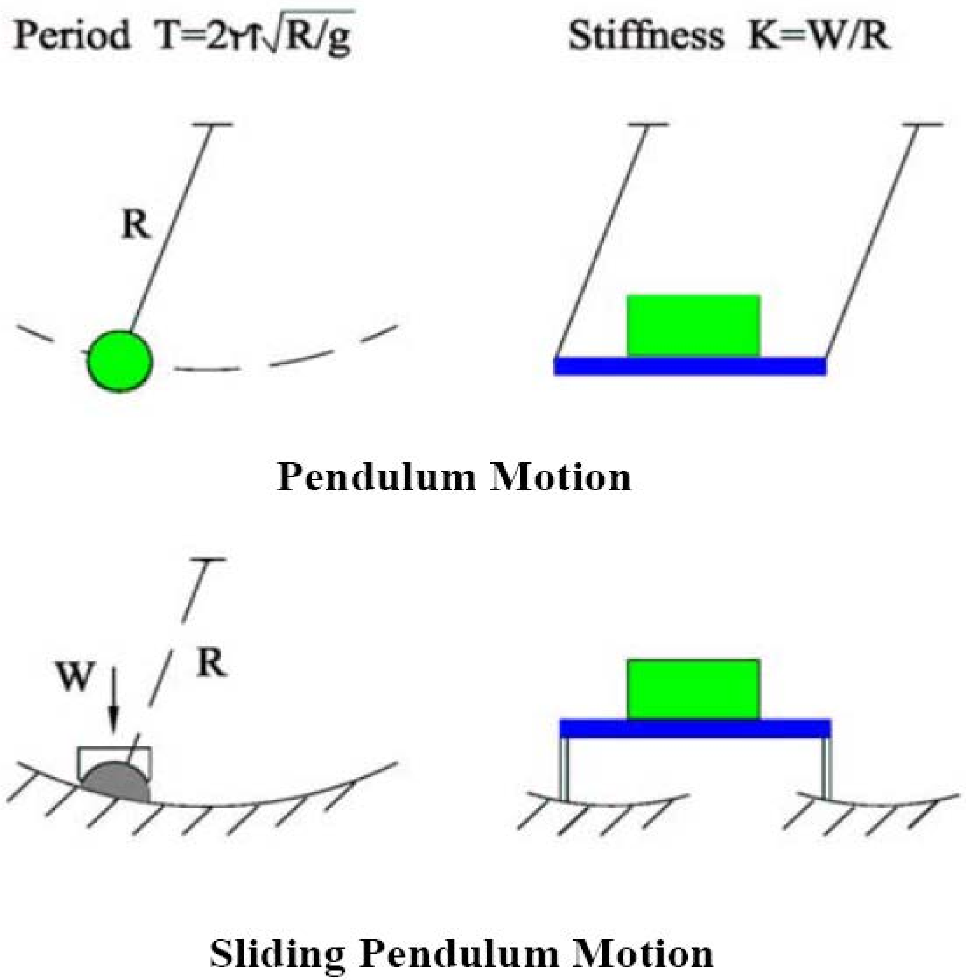
Seismic design implications

- Conventional response spectrum analysis:
  - I = 3
  - R = 3
  - Elastic design to CAN S6 475-year return period response spectrum
  - All ductility reserved for larger earthquakes

Seismic strategy

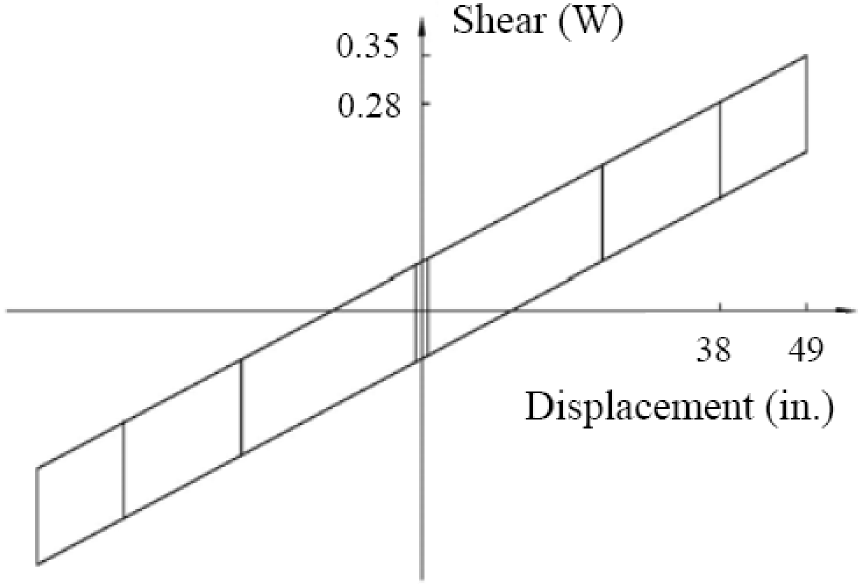
- Reduce seismic demands to less than or equal to non-seismic demands:
  - Friction pendulum bearings
  - Site-specific reduction in S6 response spectrum
- Elastic design
- Respect all ductile detailing requirements in S6

Principle of friction pendulum bearings



Source: Earthquake Protection Systems

Characteristics of single pendulum bearings



 Source: Earthquake Protection Systems

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Examples of EPS single pendulum bearings

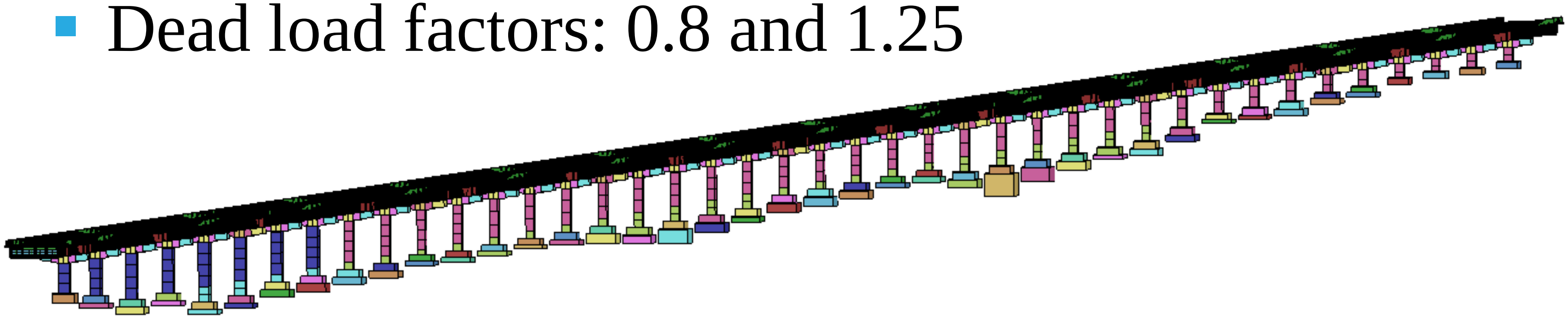
Typical Single Pendulum Bearing

Single Pendulum Bearing for
Sakhalin II Offshore Oil Platform

 Source: Earthquake Protection Systems

Seismic analysis

- Non-linear time history analysis
- LS-DYNA: explicit, dynamic, non-linear, inelastic finite element program
- Isolators: bi-directional coupled plasticity model verified by testing
- Hydrodynamic effect: added mass method
- Dead load factors: 0.8 and 1.25



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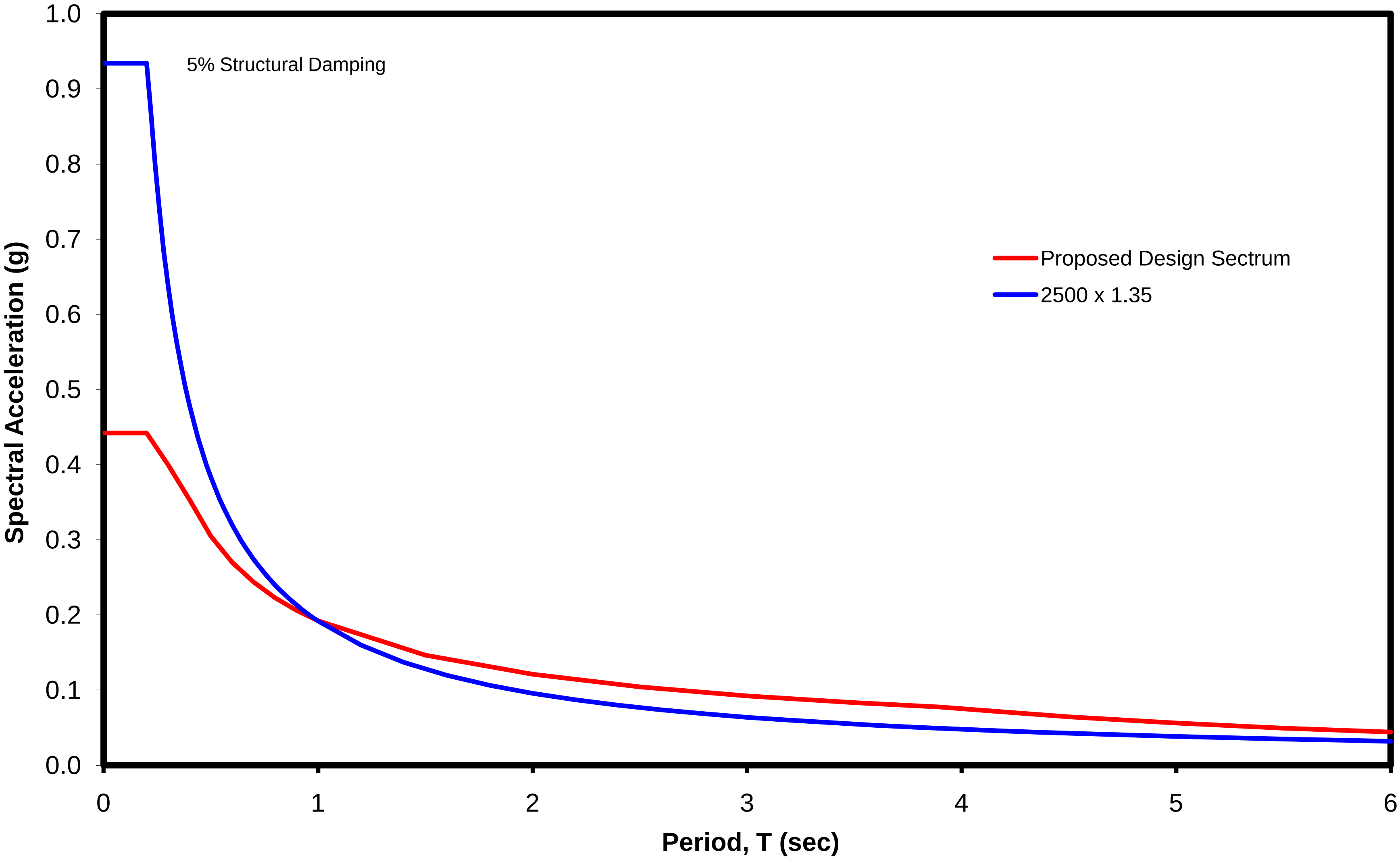
Seismic analysis

- 2 response spectra evaluated:
  - 0.8 x CAN S6 spectrum, I = 1, rock or stiff soil
  - 1.35 x GSC site-specific 2500-year uniform hazard spectrum
- 5 time histories matched to each spectrum using RSPMatch
- Wave passage effect: 2 different wave speeds:
  - 1500 m/s
  - 2500 m/s

Response spectra



Parametric study

Single-pendulum bearing characteristics:

- 1.8 sec sliding period with 3% sliding friction
- 2.0 sec sliding period with 4% sliding friction
- 2.2 sec sliding period with 4% sliding friction
- 3.0 sec sliding period with 5% sliding friction

Proposed spectrum ($0.8C_{sm}$)

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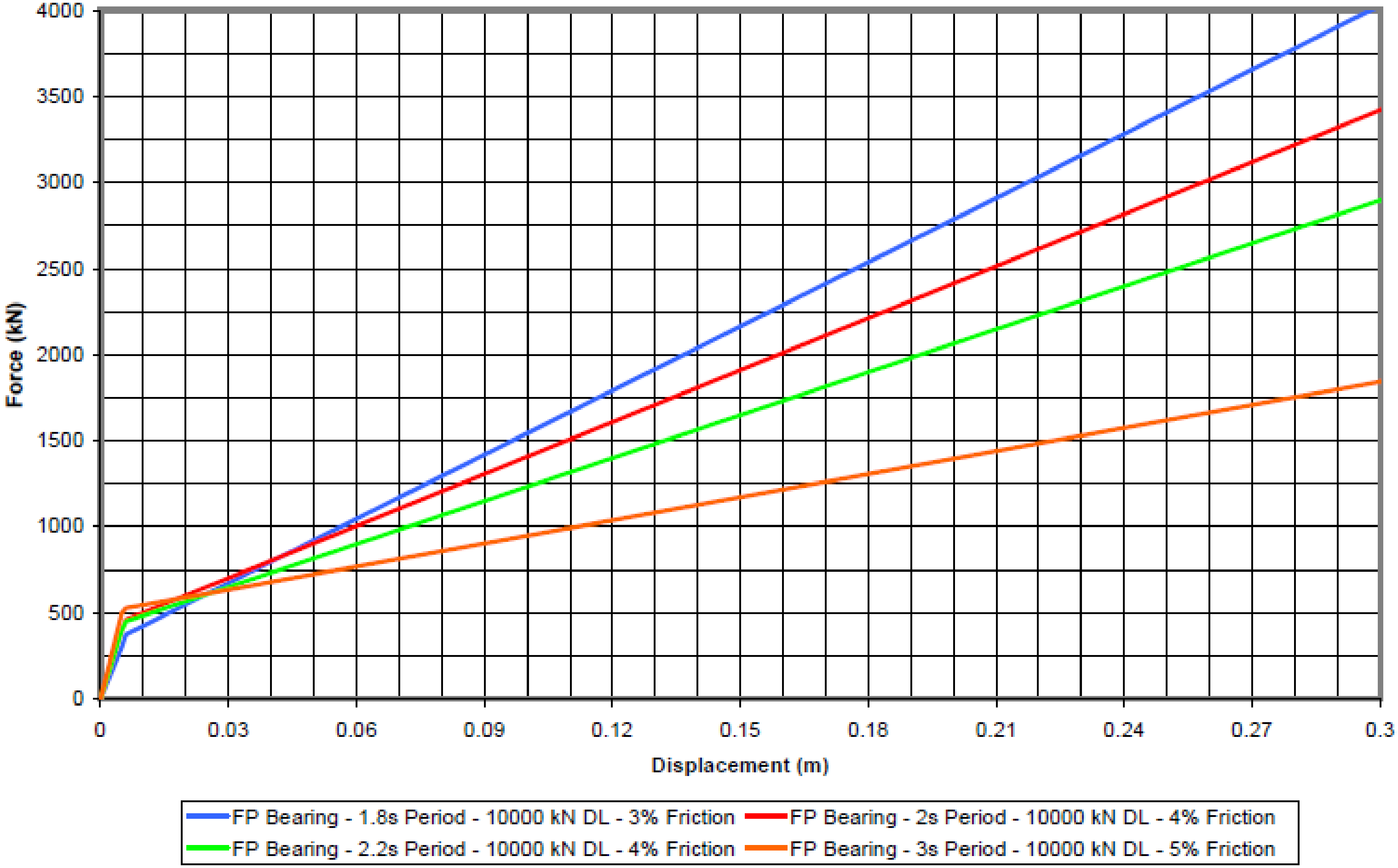
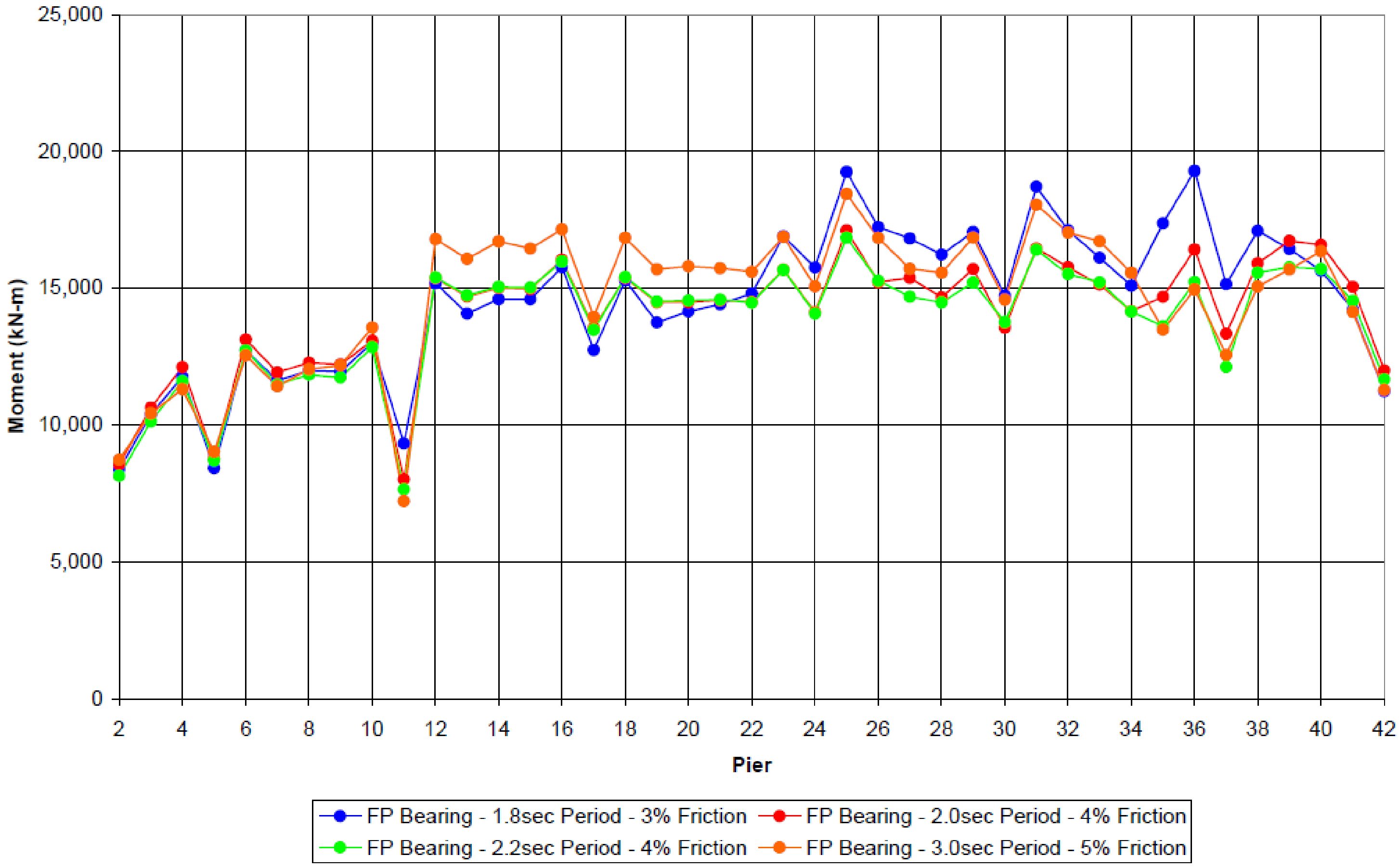
Force-displacement curves

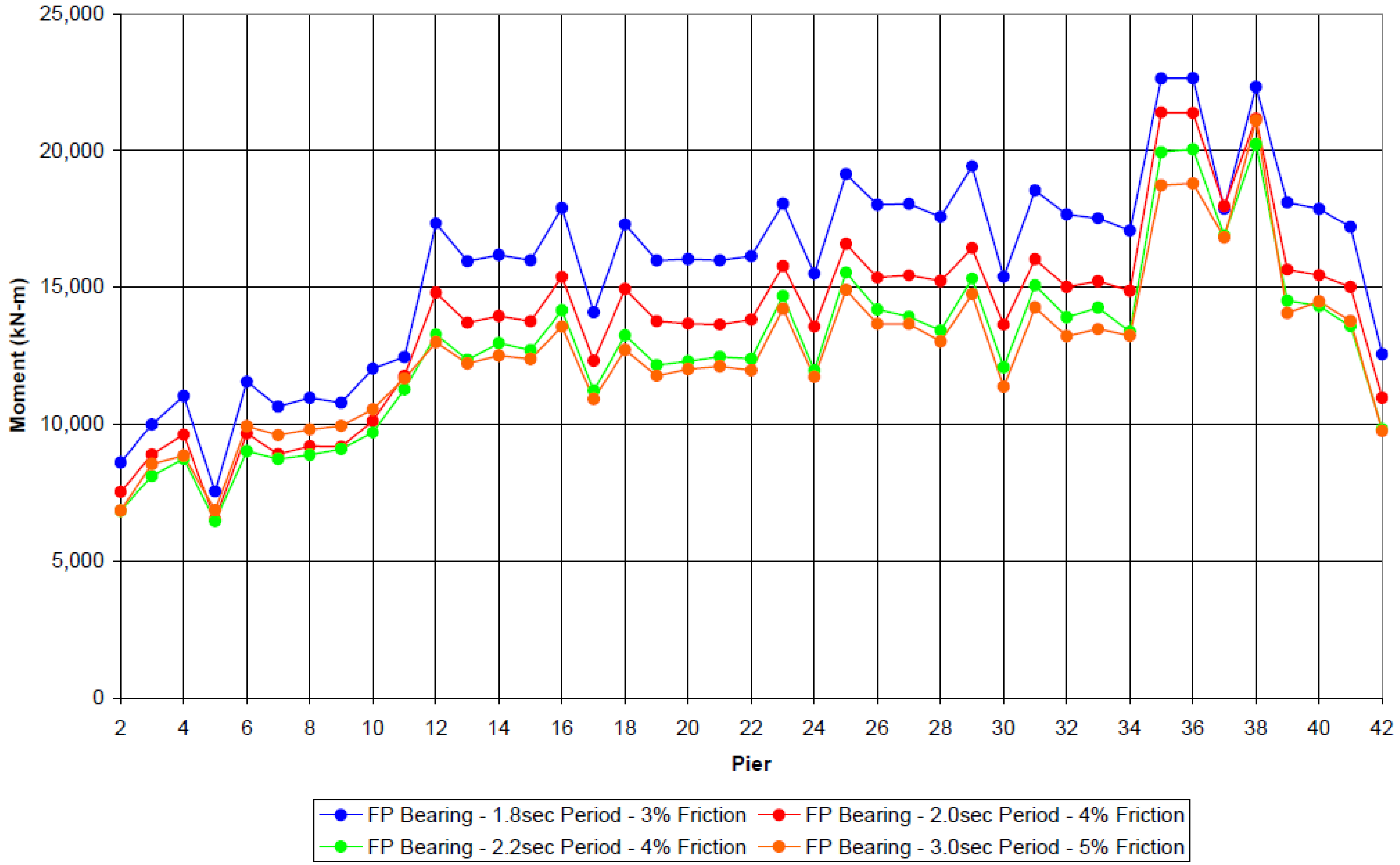


Parametric study results



Column Longitudinal Base Moments

Parametric study results



Column Transverse Base Moments

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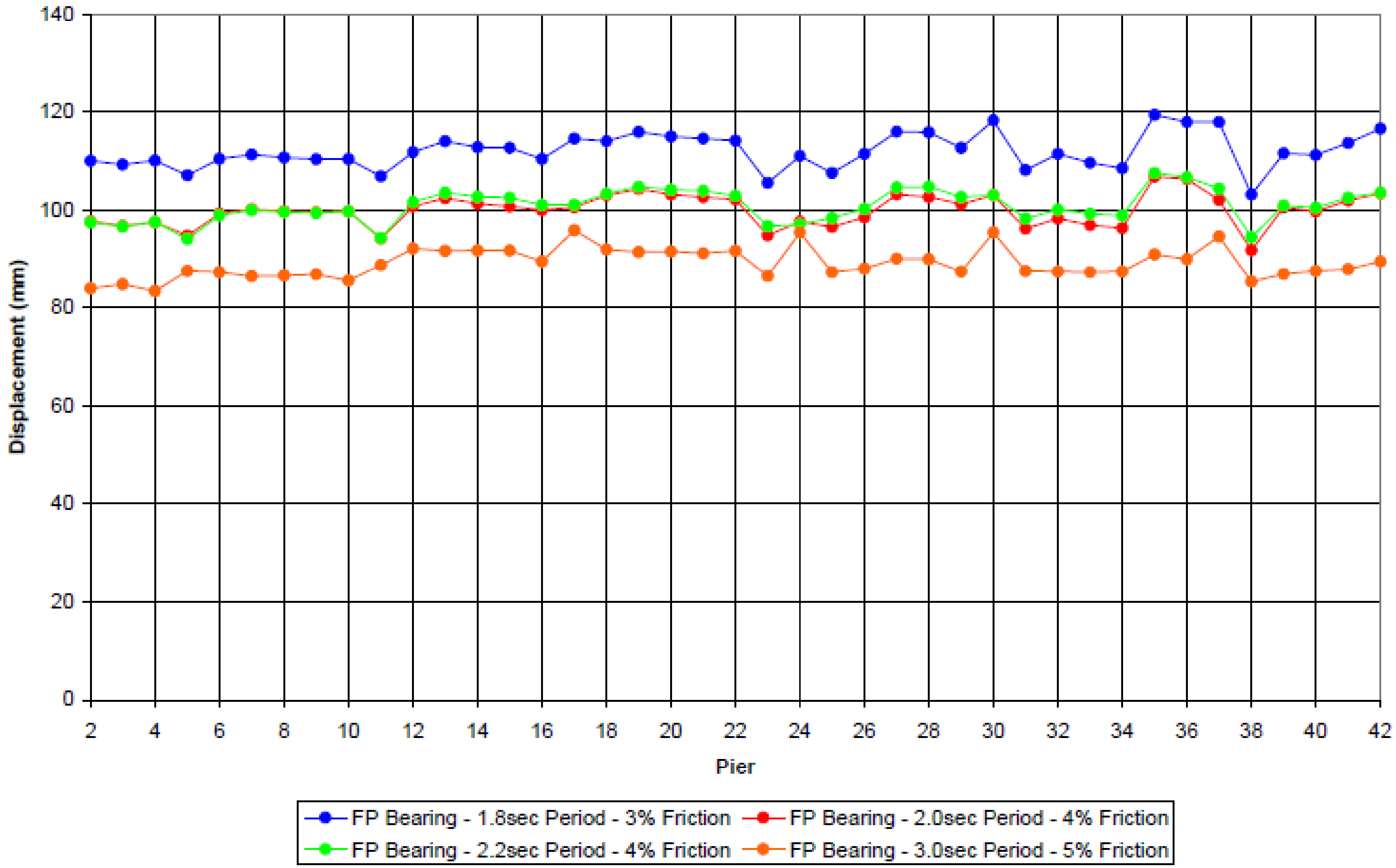
Parametric study results



Bearing Longitudinal Displacements

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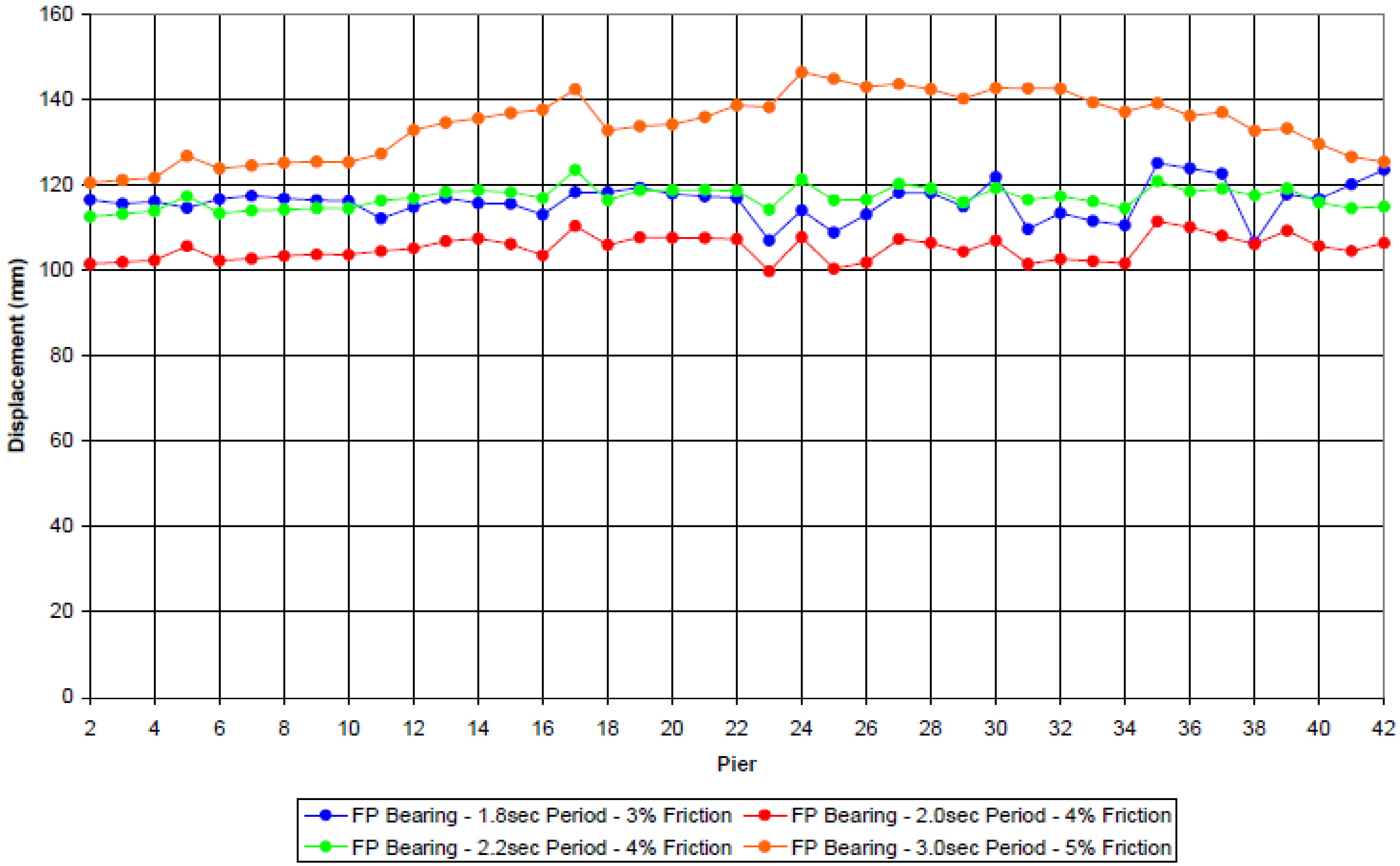
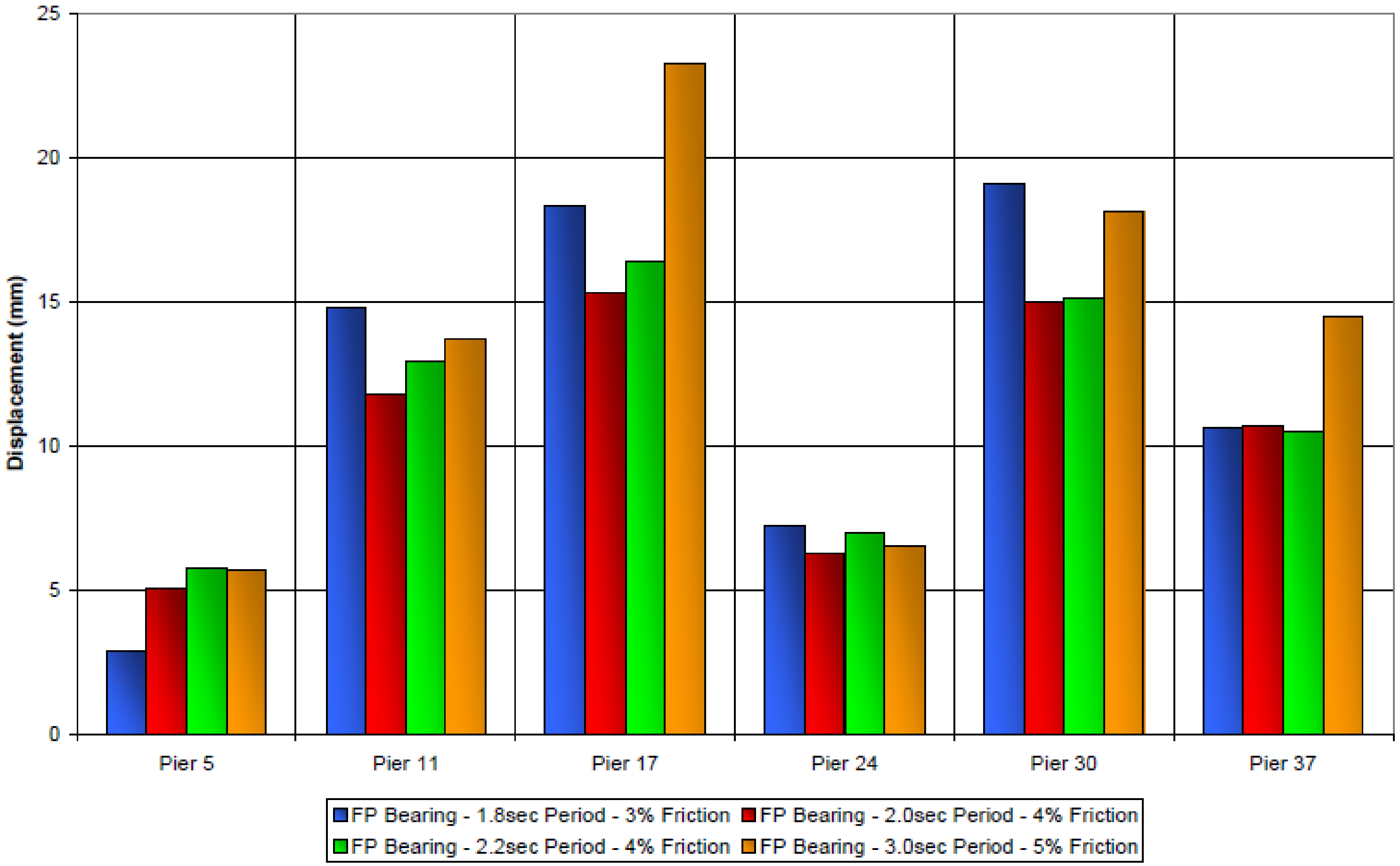
Parametric study results



Bearing Transverse Displacements

Parametric study results



Expansion Joint Transverse Displacements

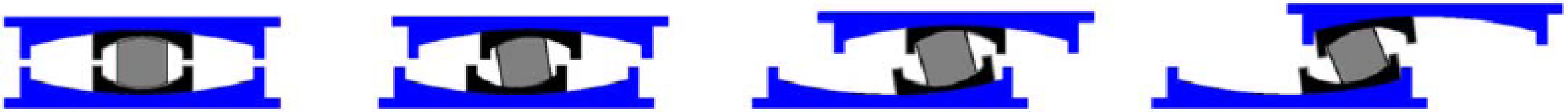
Selected characteristics

2.2 sec period with 4% friction

Subsequent changes:

- Number of expansion joints increased from 6 to 7
- Size of diaphragms increased
- Changes to founding elevations and column lengths
- Shear keys added across expansion joints
- EPS proposed triple pendulum bearings for piers
- 1.35 x GSC 2500-year spectrum added

EPS triple pendulum bearings



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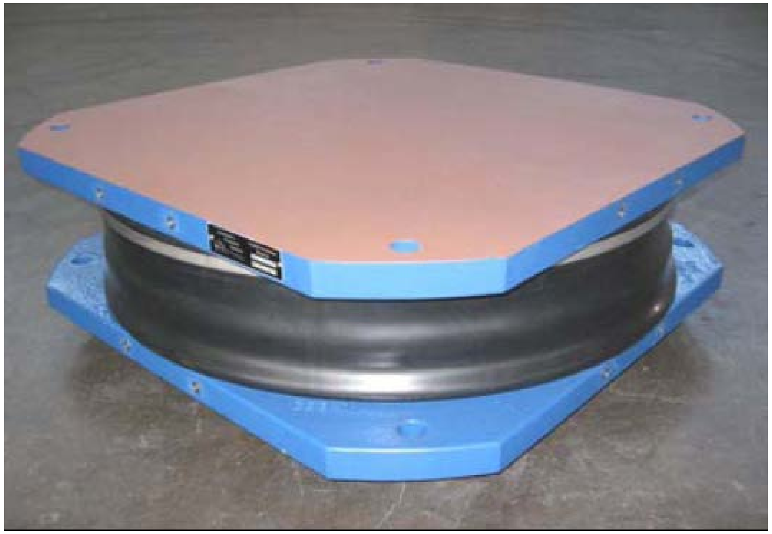
EPS triple pendulum bearings



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EPS triple pendulum bearings

YAS Island Hotel and Marina Link Bridge
Abu Dhabi

Friction pendulum bearing on-site

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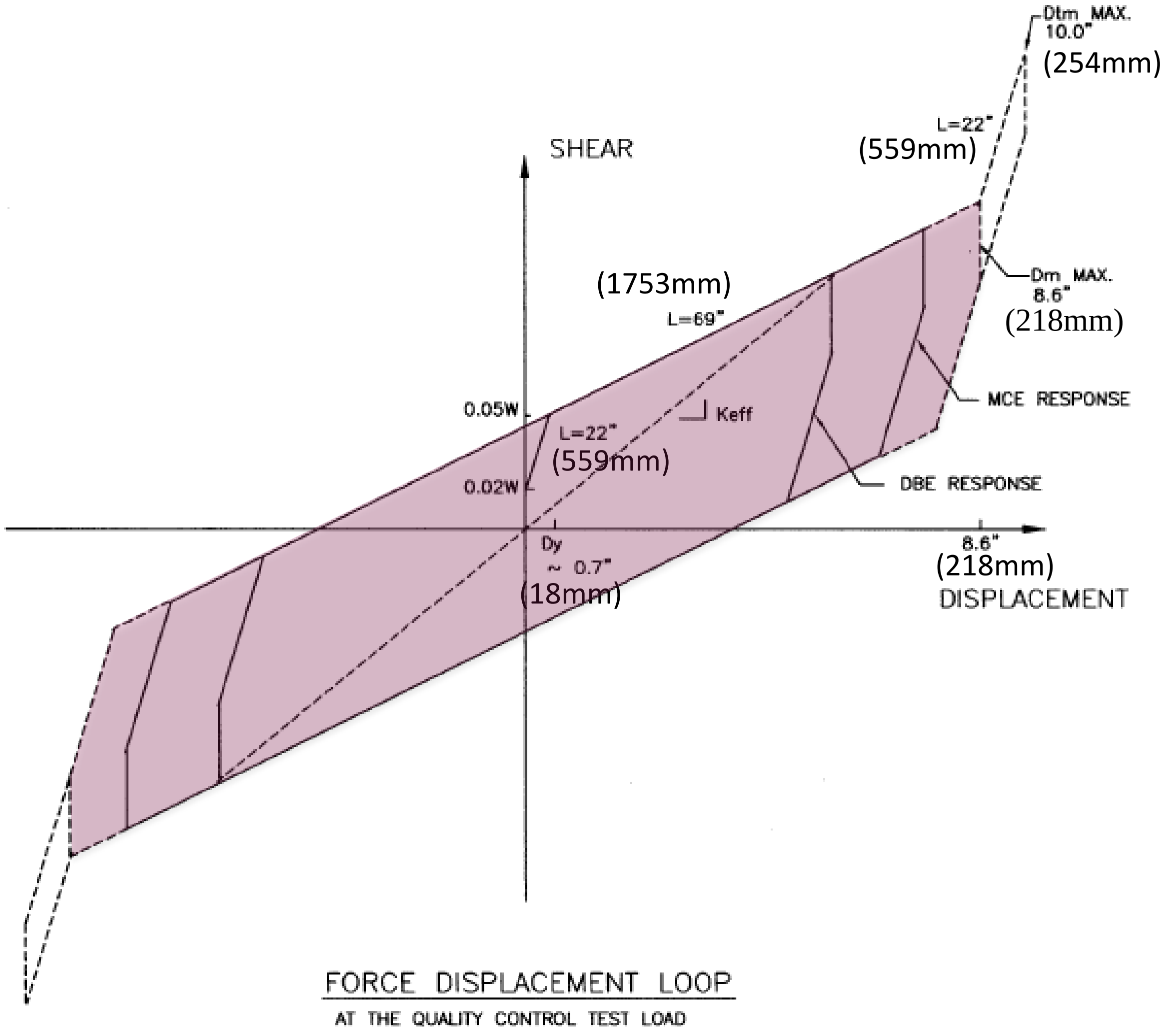
Triple pendulum bearing characteristics



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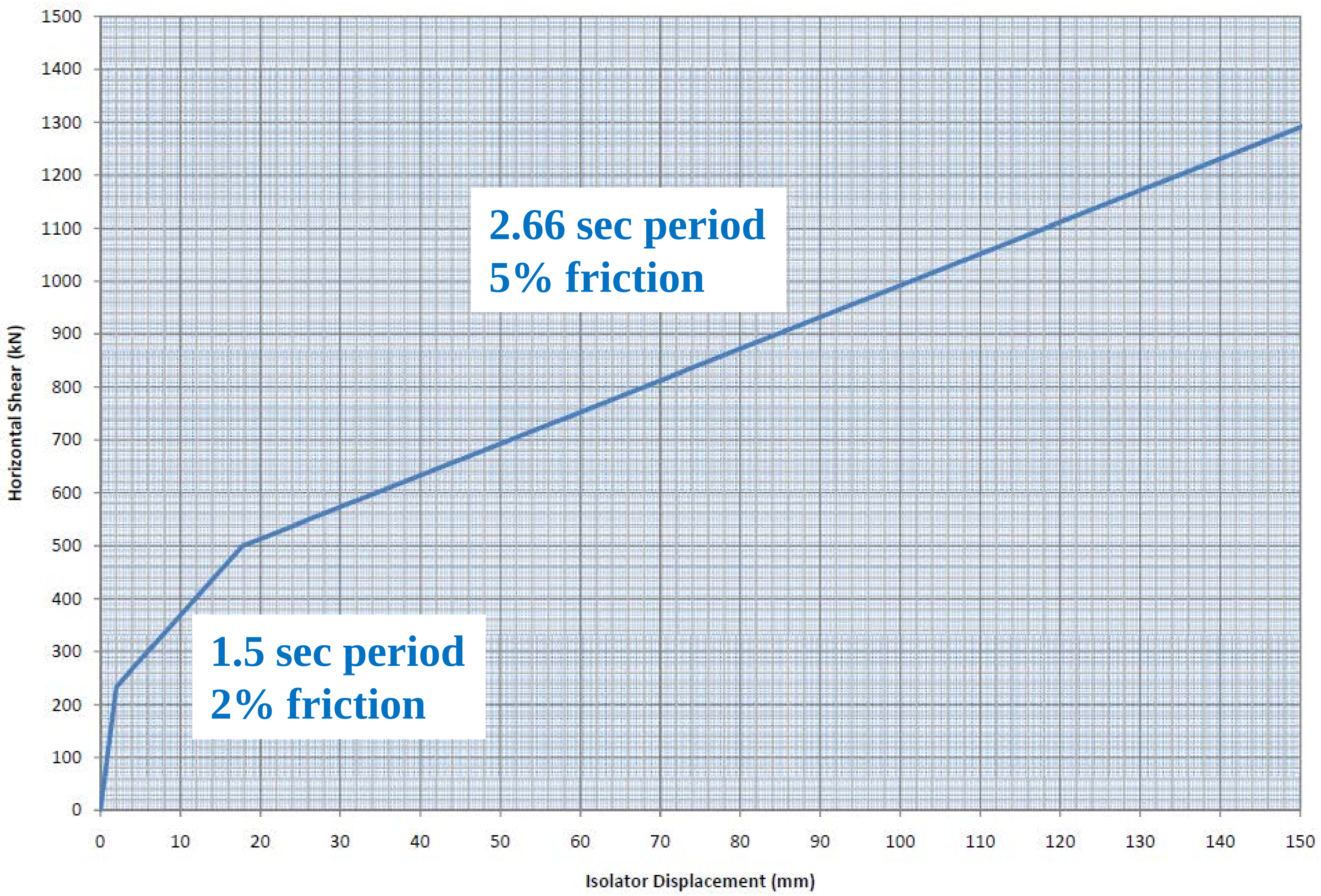
Triple pendulum bearing characteristics
Force-displacement curve



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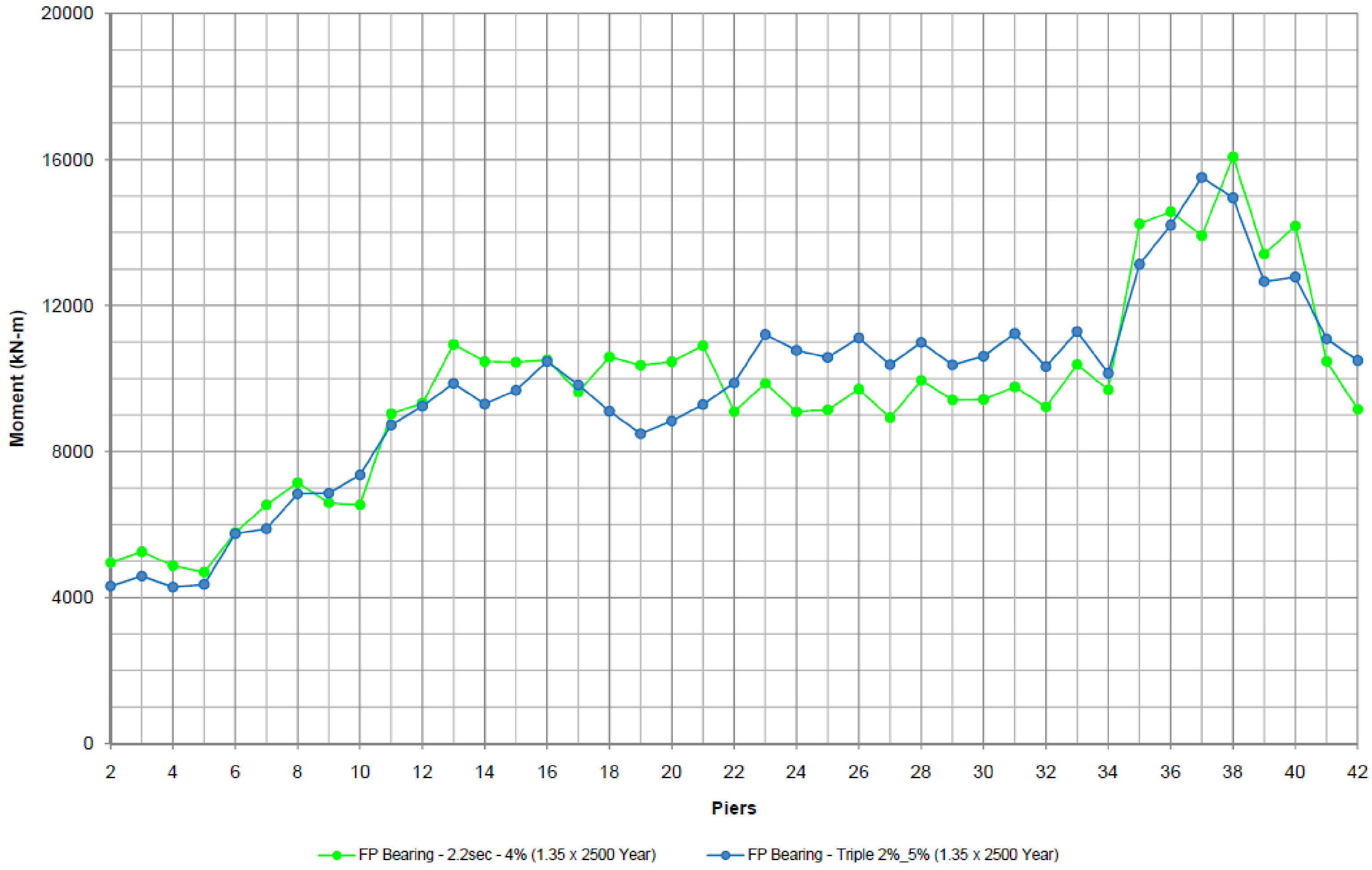
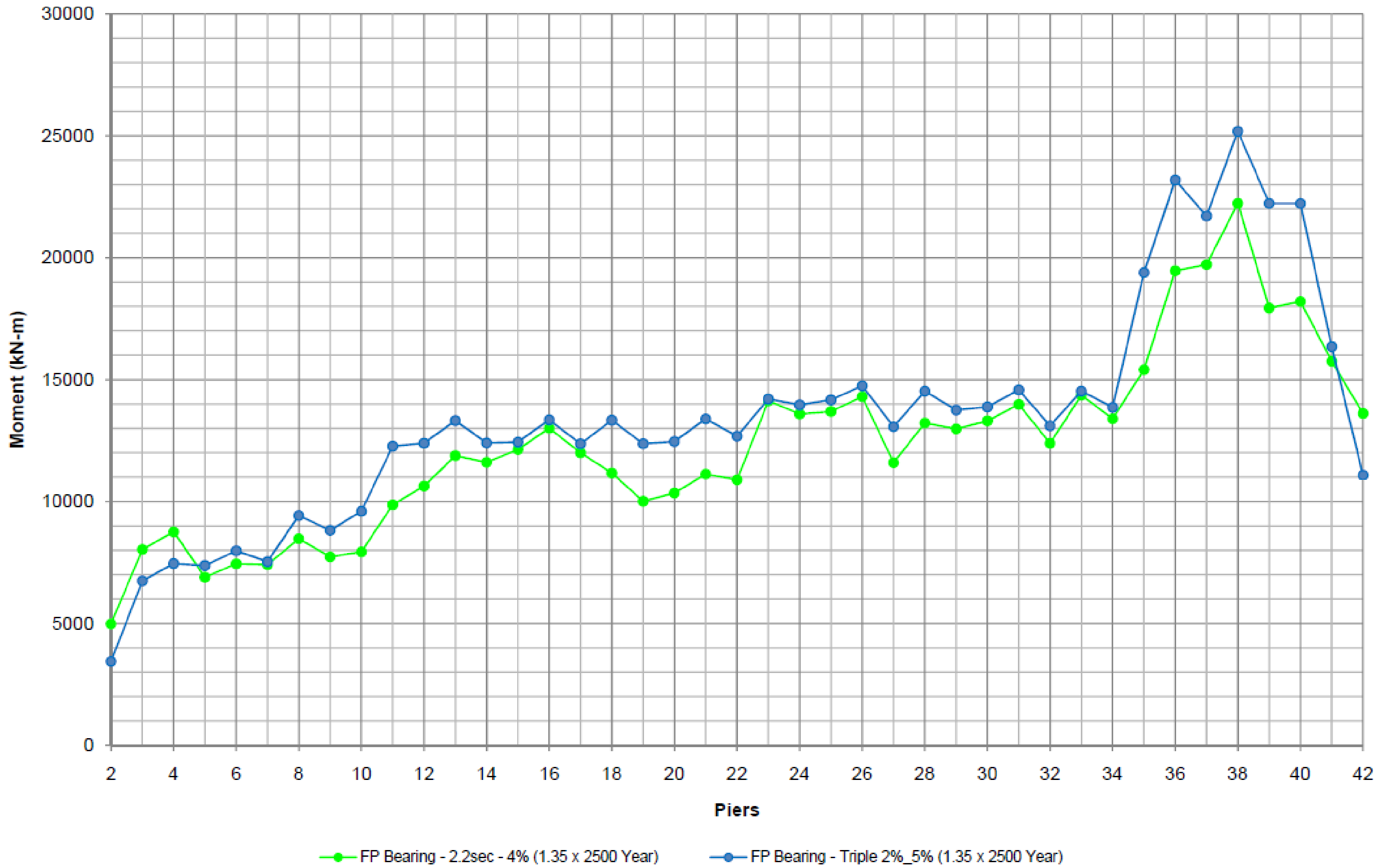
Single pendulum vs. triple pendulum results



Column Longitudinal Base Moments

Single pendulum vs. triple pendulum results



Column Transverse Base Moments

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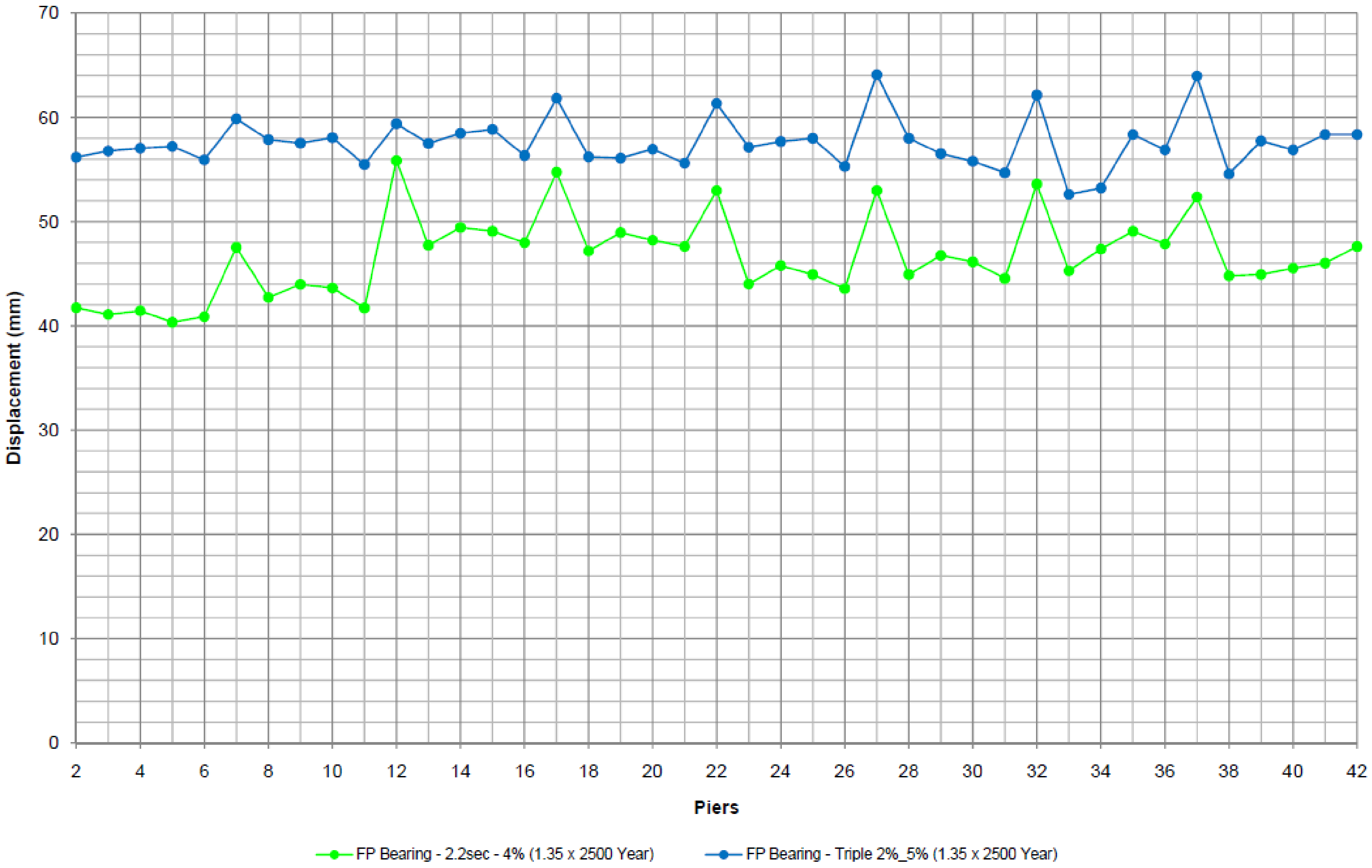

Bearing Longitudinal Displacements

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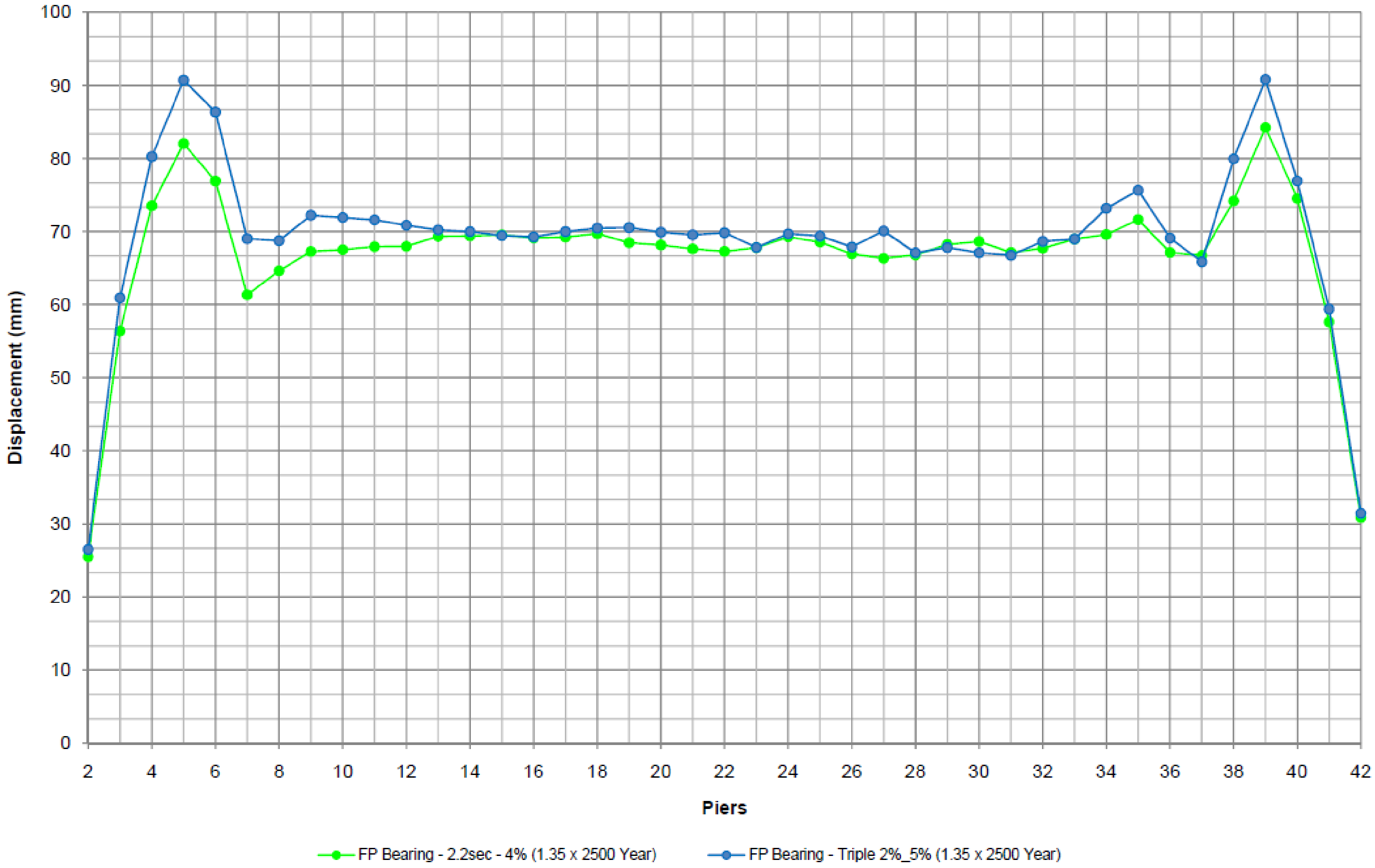
Single pendulum vs. triple pendulum results



Bearing Transverse Displacements

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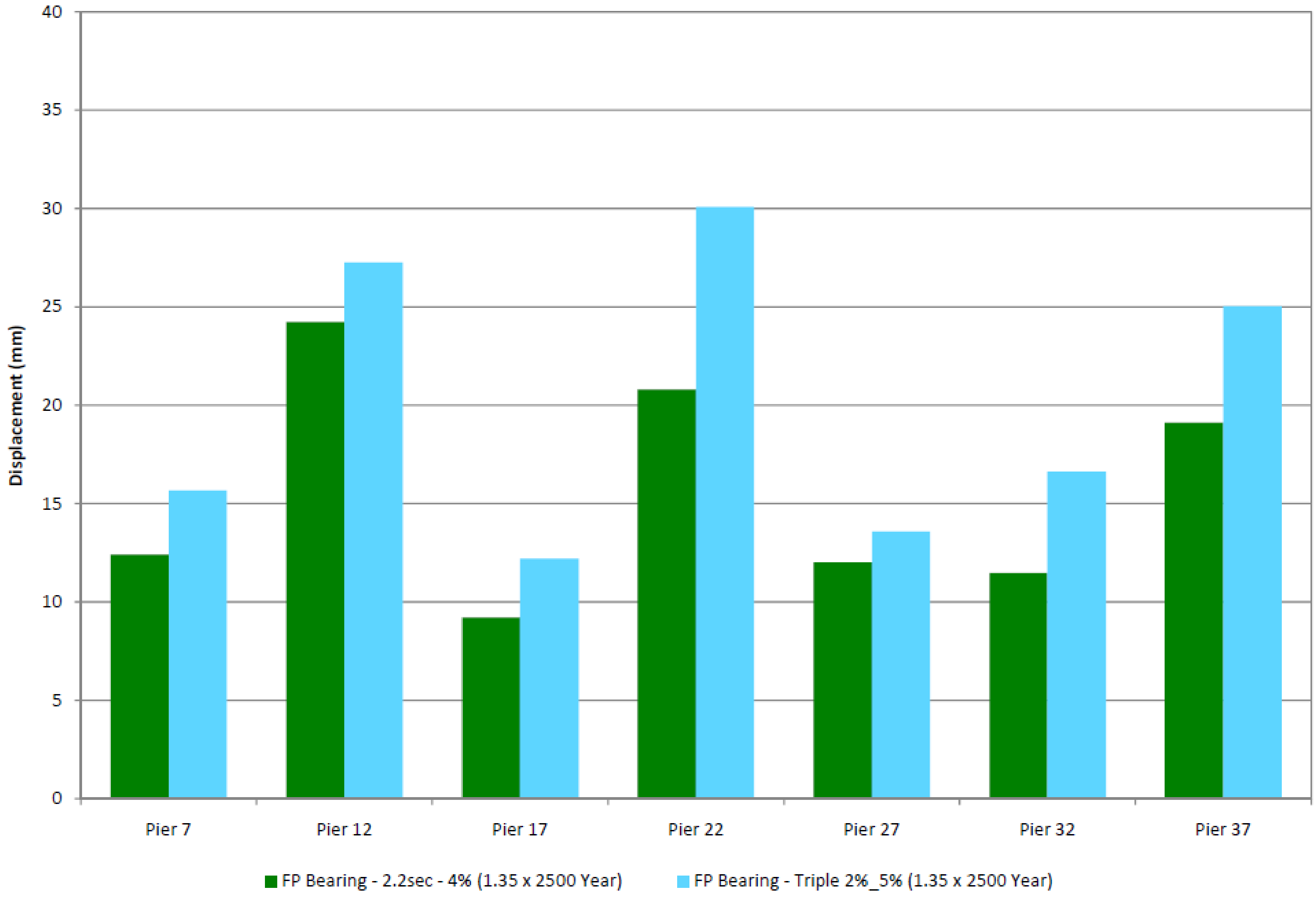
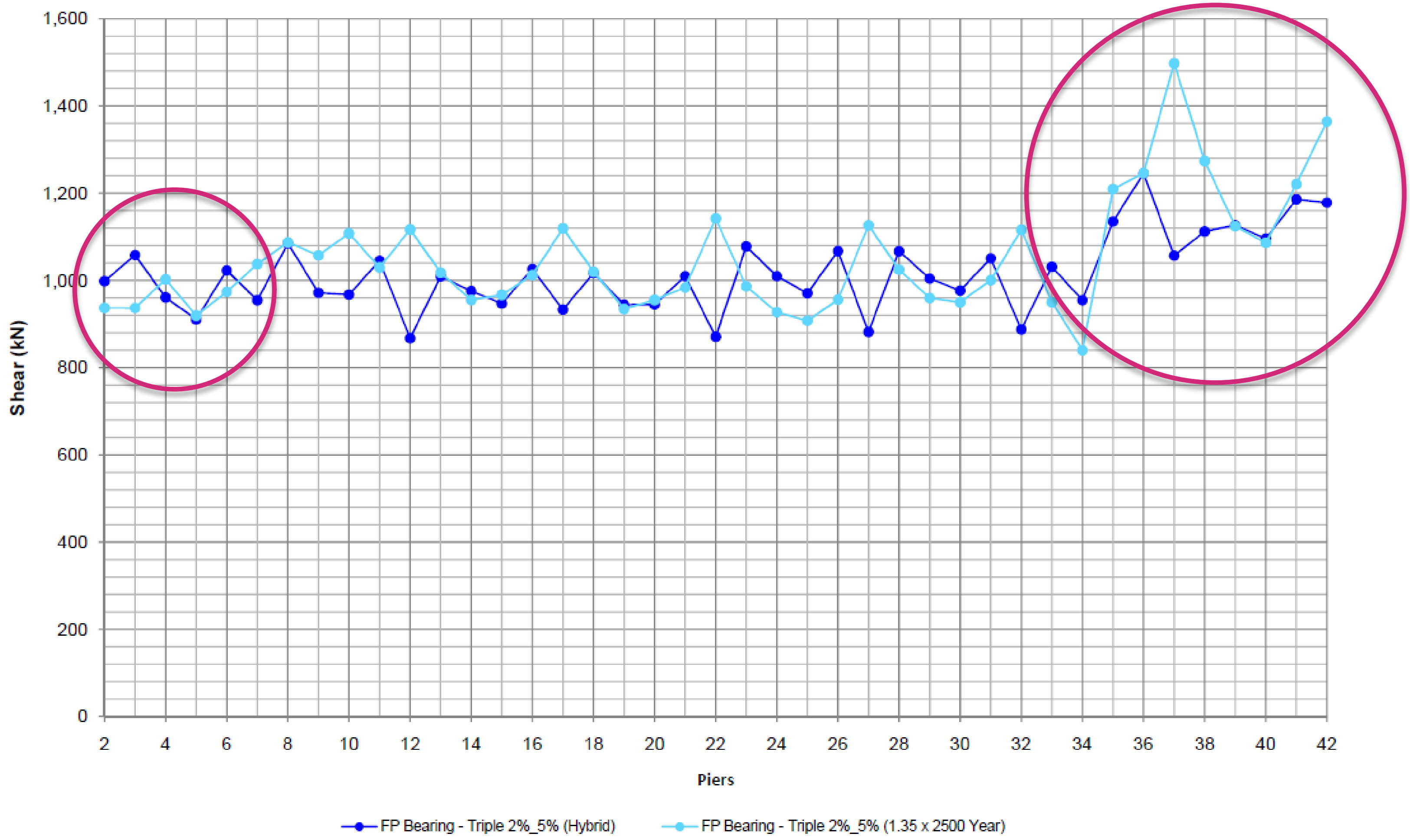


Expansion Joint Longitudinal Displacements (opening)

Observations

- Bridge response somewhat more favorable with single pendulum bearings
- Bridge response with triple pendulum bearings is acceptable
- Triple pendulum bearings smaller, less costly, greater excess movement capacity

Spectra comparison study results



Column Longitudinal Shear Force

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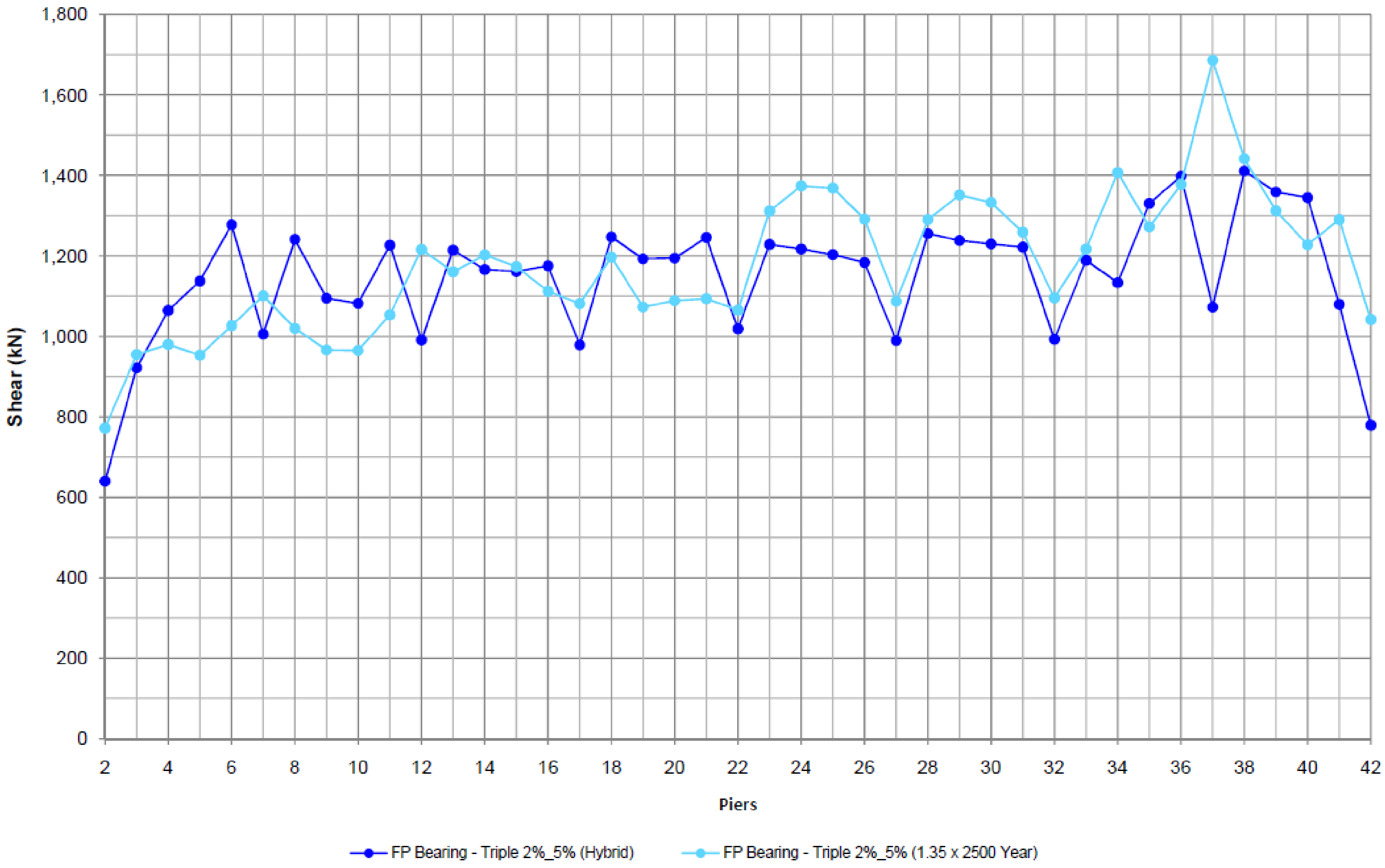
Spectra comparison study results



Column Transverse Shear Force

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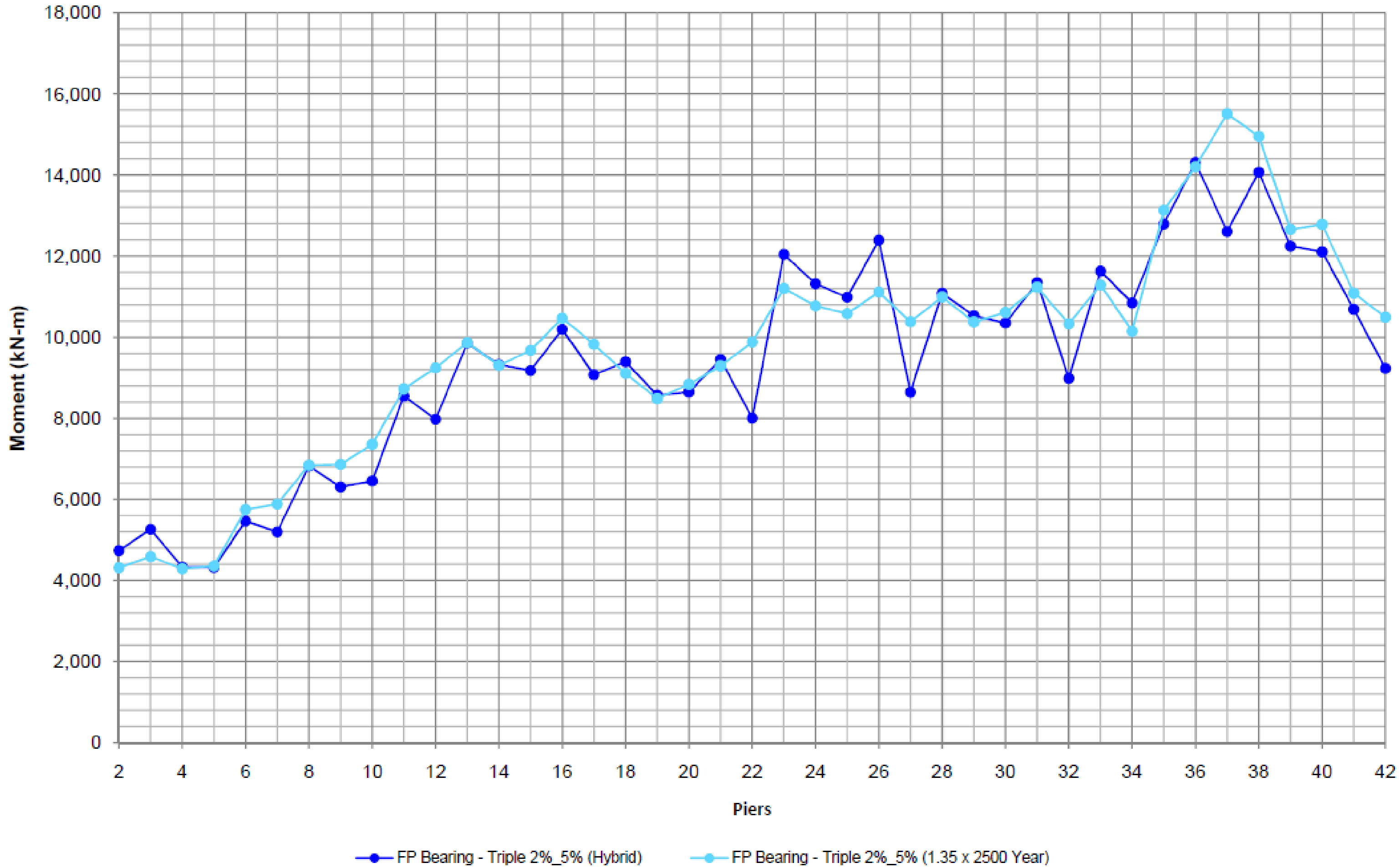
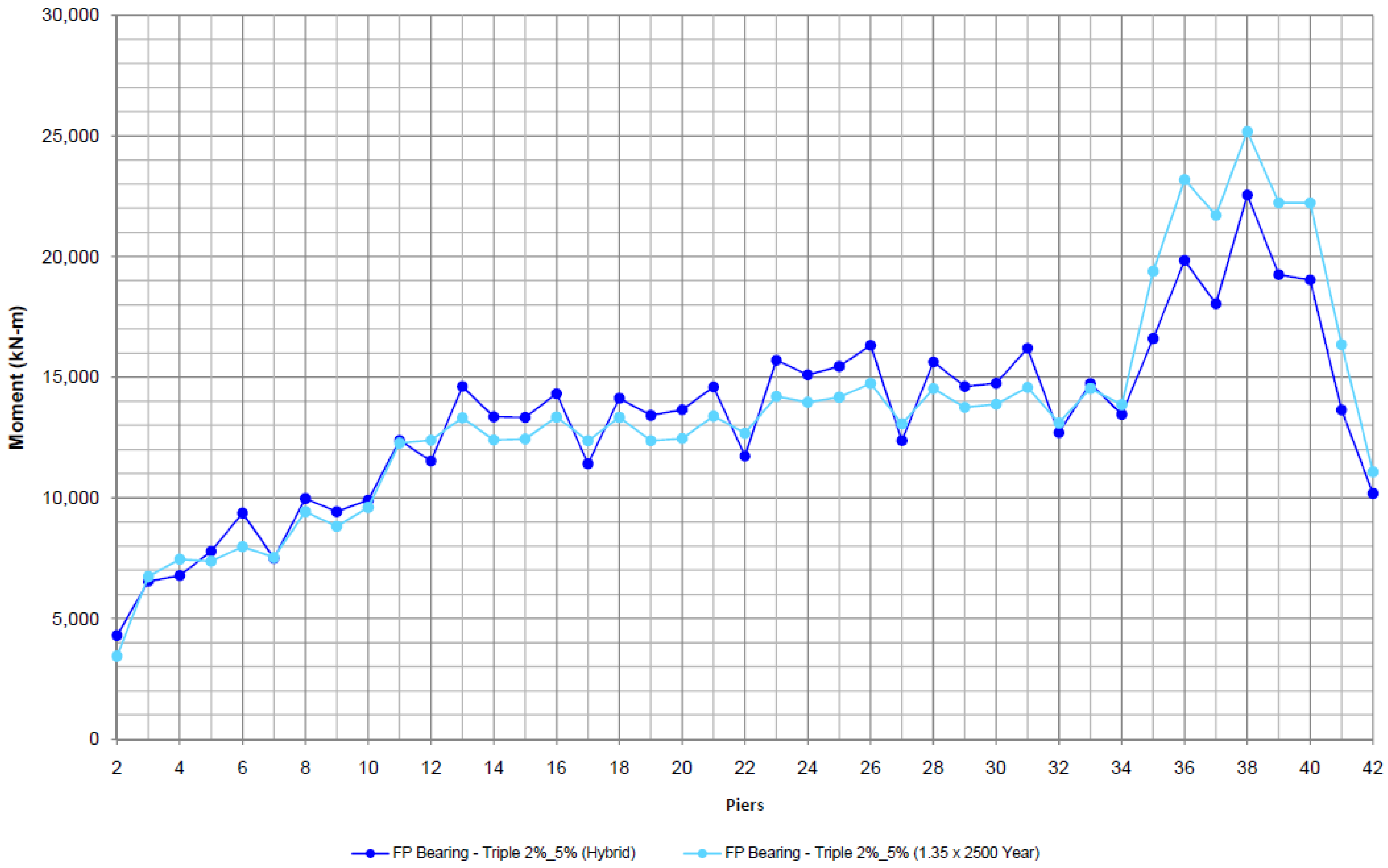
Spectra comparison study results



Column Longitudinal Base Moments

Spectra comparison study results



Column Transverse Base Moments

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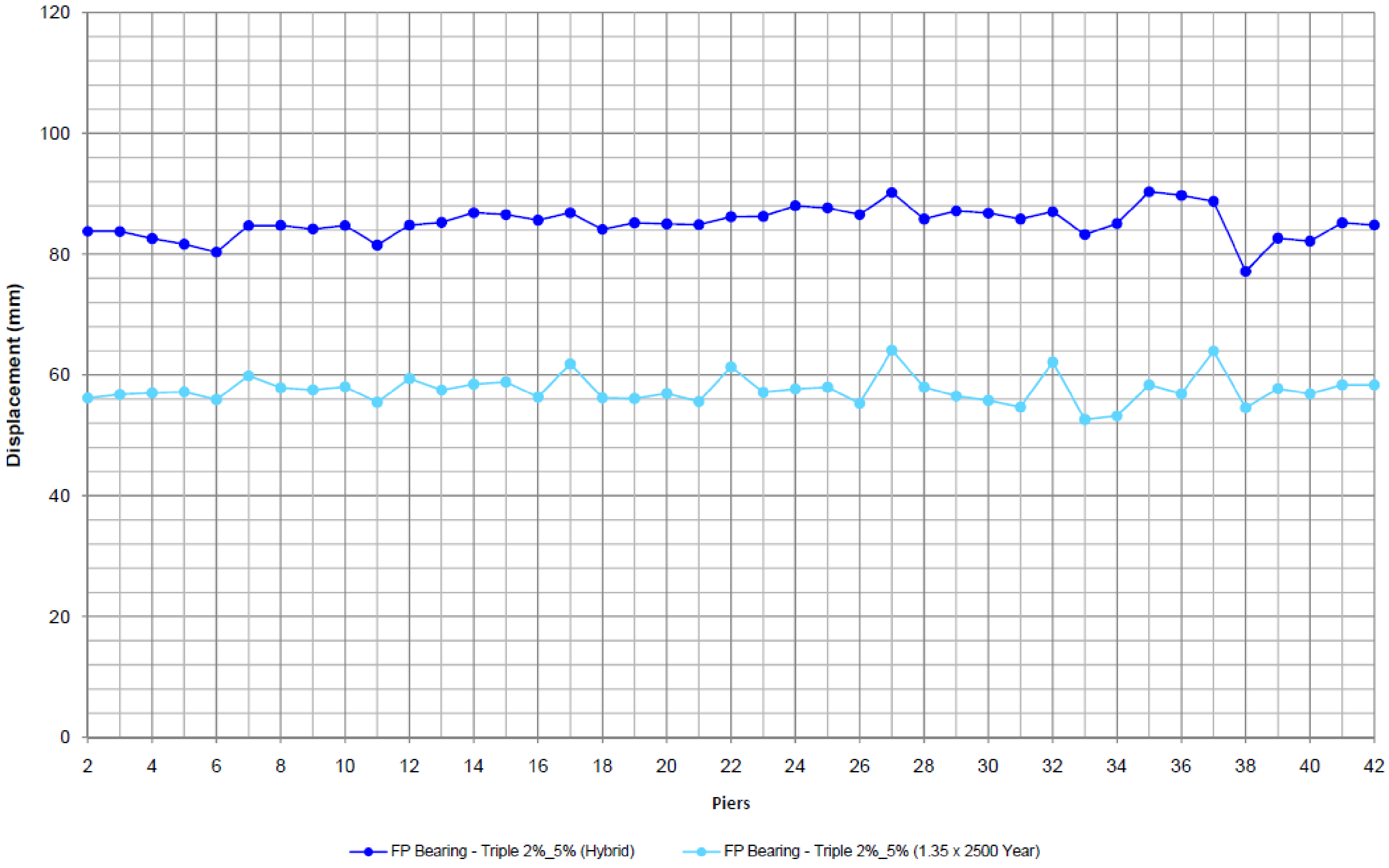

Bearing Longitudinal Displacements

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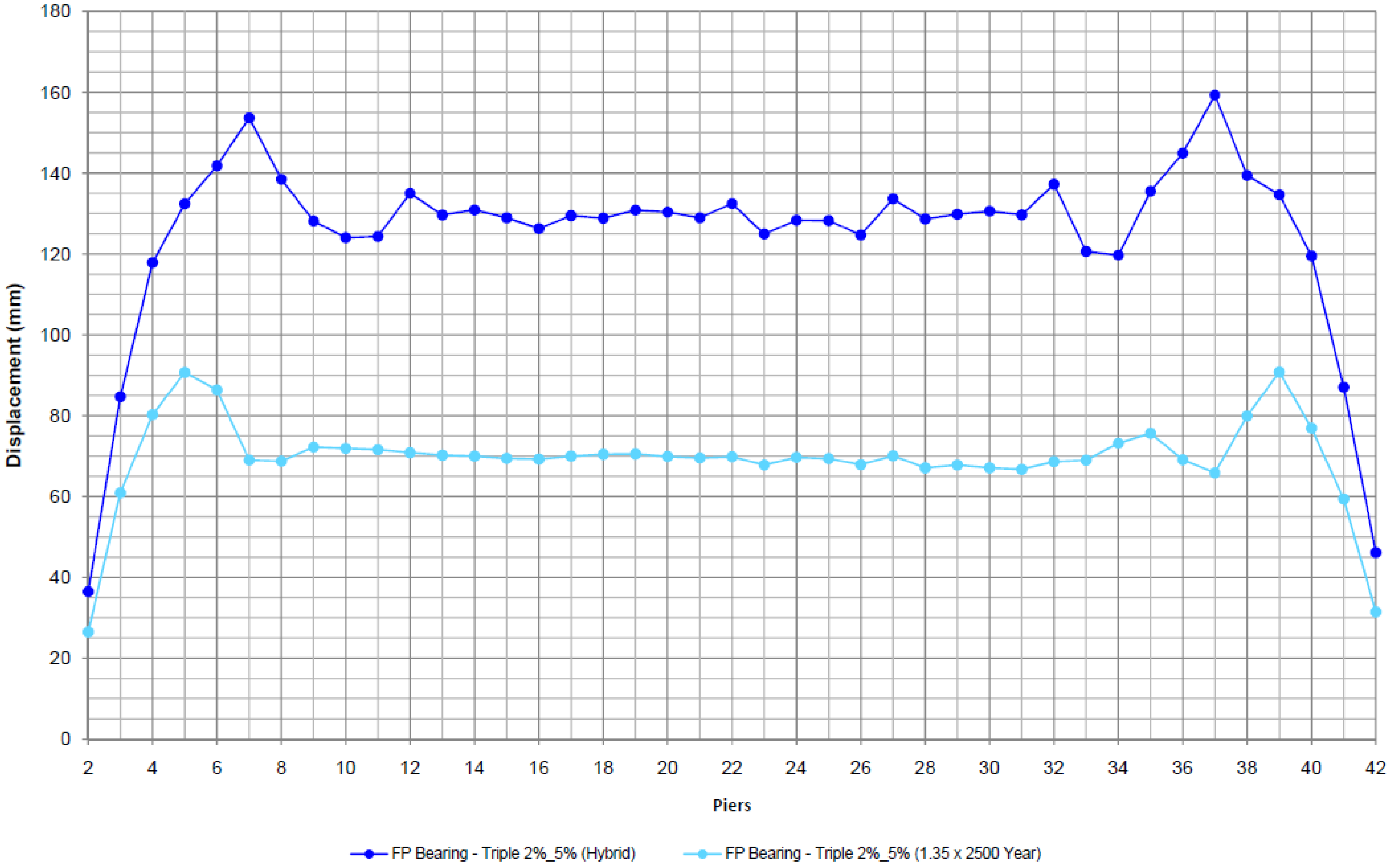

Bearing Transverse Displacements

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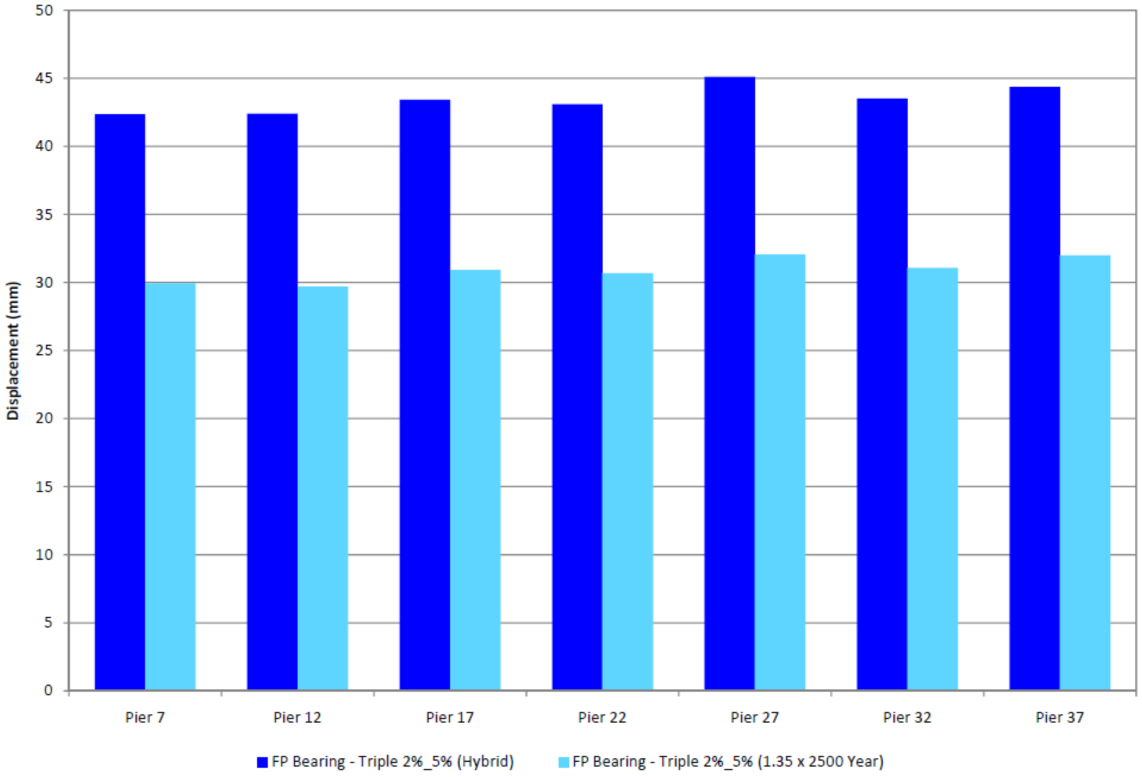

Expansion Joint Longitudinal Displacements (opening)

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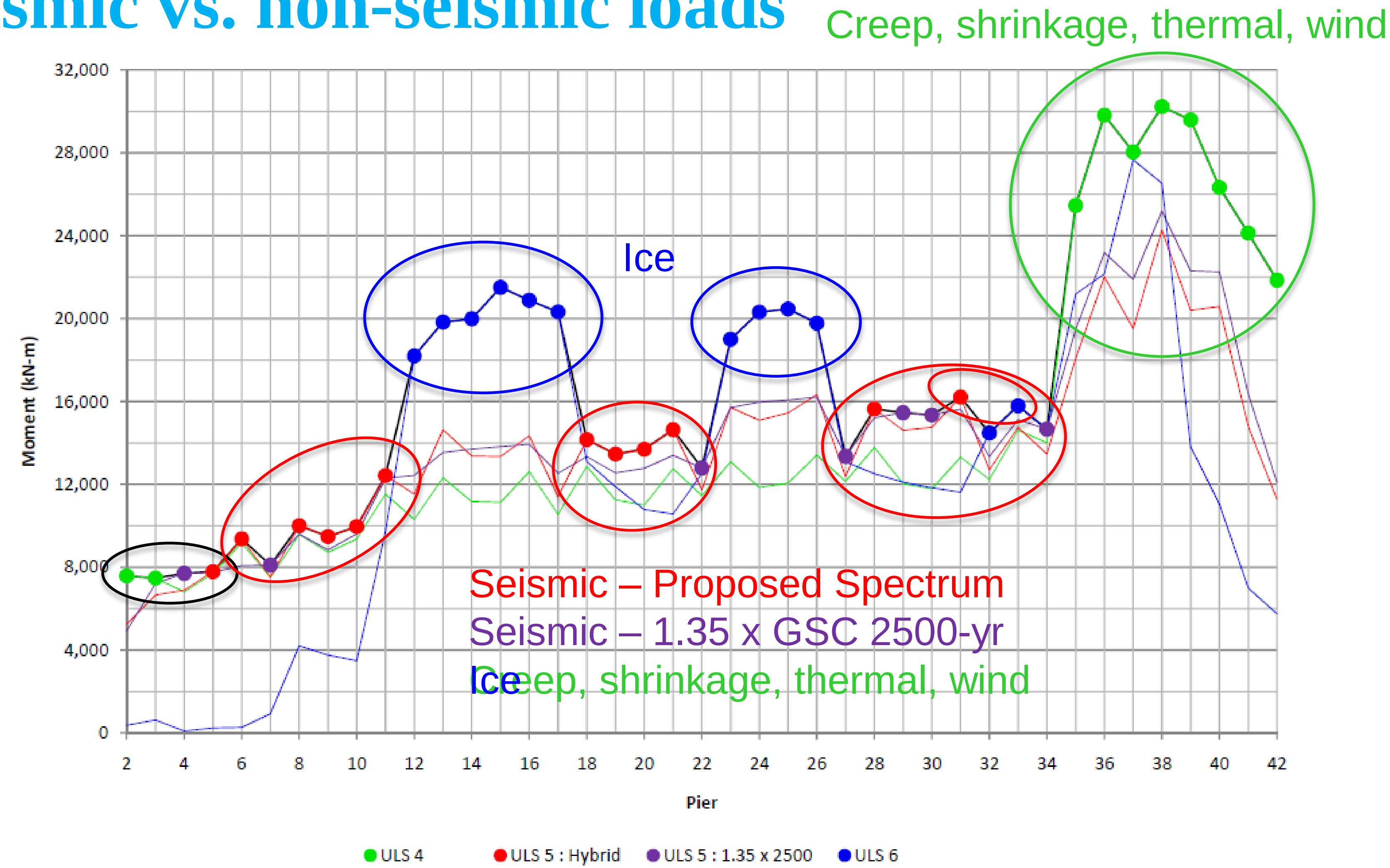
Observations

- Overall, the force effects are comparable
- Overall, displacements are greater under the proposed spectrum
- The taller, larger diameter columns are more sensitive to the short period shaking than the shorter, smaller diameter columns
- Average damping is 24%

Seismic vs. non-seismic loads



Comparison of governing column base moments

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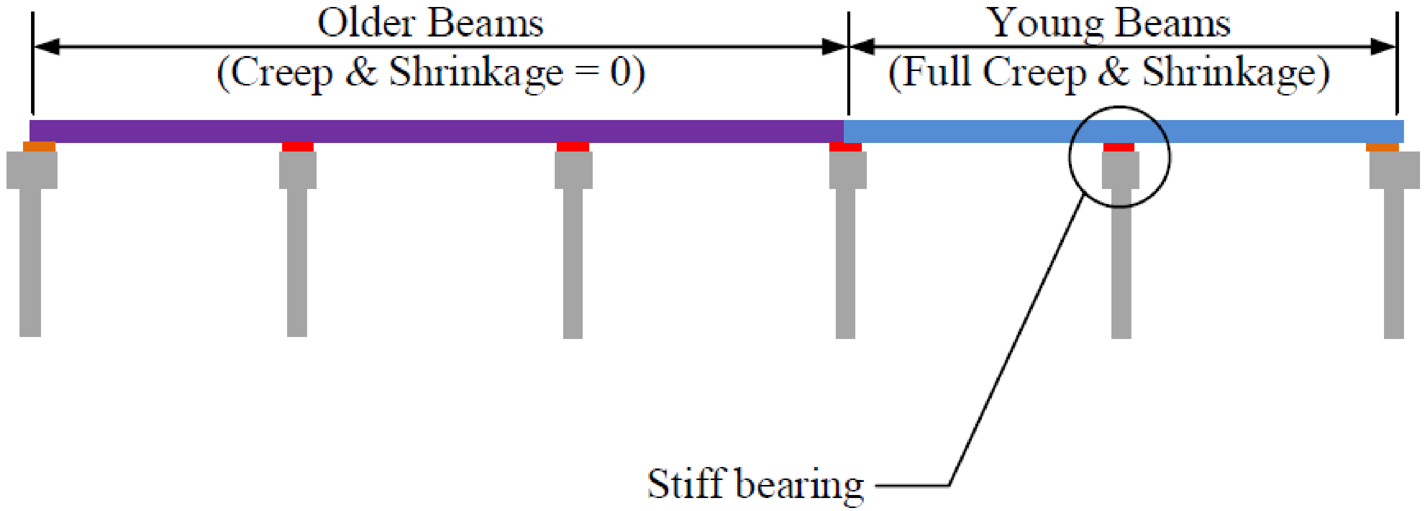
Walking study



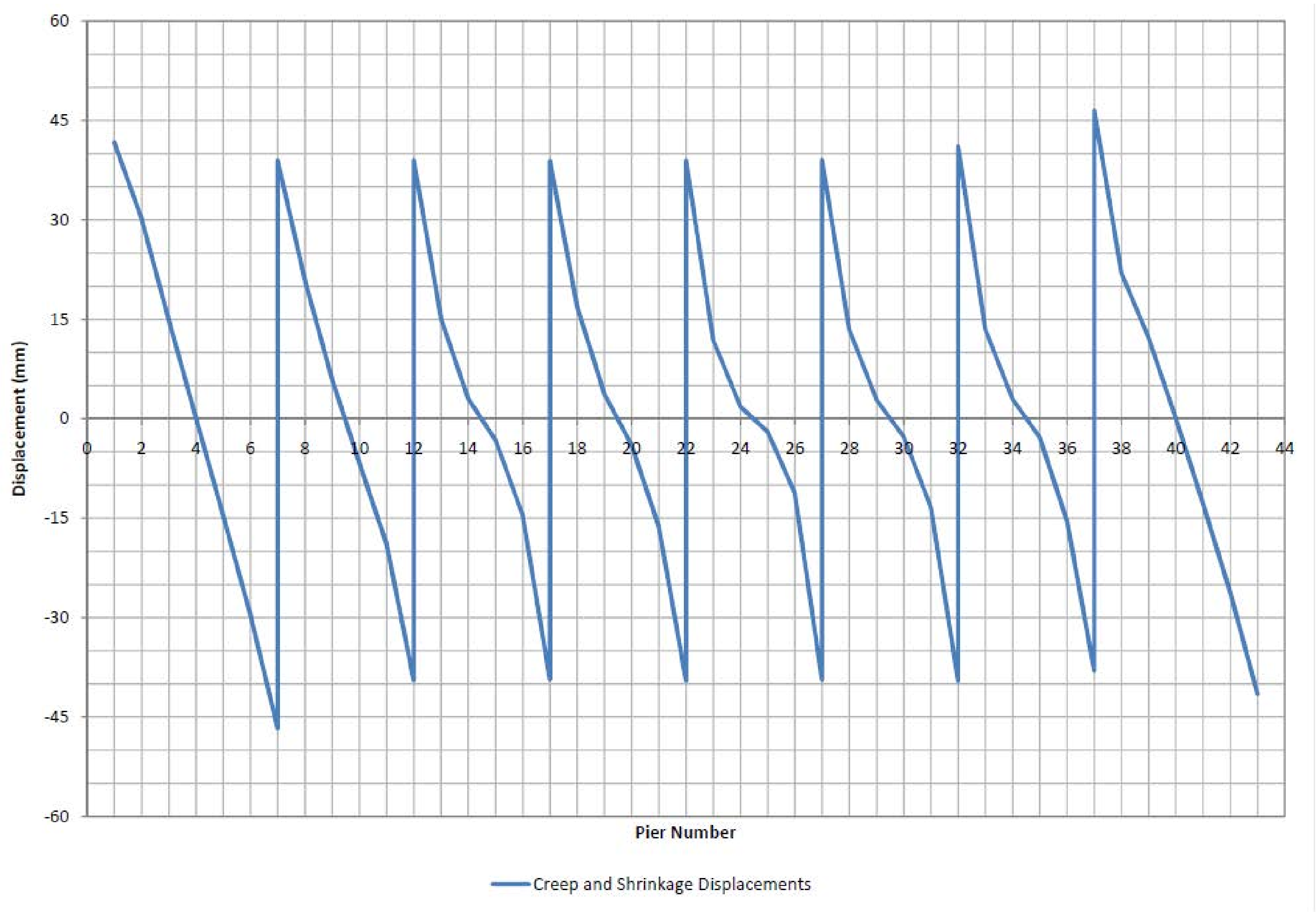
Five span unit: 40mm
Six span unit: 42mm
85% of average: 35mm

Displacements

Bearing	Design Displacements			MCE Capacity	Capacity -to- Demand Ratio	Max Capacity
	ULS 4 (Non-seismic)	ULS 5 (Seismic)	Seismic + ½ Thermal			
Continuity Piers	120	146	170	218	1.28	254
Expansion Piers	169	162	198	241	1.22	279
Abutments	152	87	120	254	1.67	254

- FP bearings cannot be offset for temperature
- Accounted for in seismic + ½ thermal load case

Creep and shrinkage



Creep and Shrinkage Displacements

Conclusions

- Isolation successfully mitigated seismic demands as a governing load case under both design spectra
- Both single-pendulum and triple-pendulum bearings were feasible
- Triple-pendulum bearings were less costly, smaller and provided greater excess movement capacity
- Walking, and creep / shrinkage must be accounted for in displacement design of FP bearings