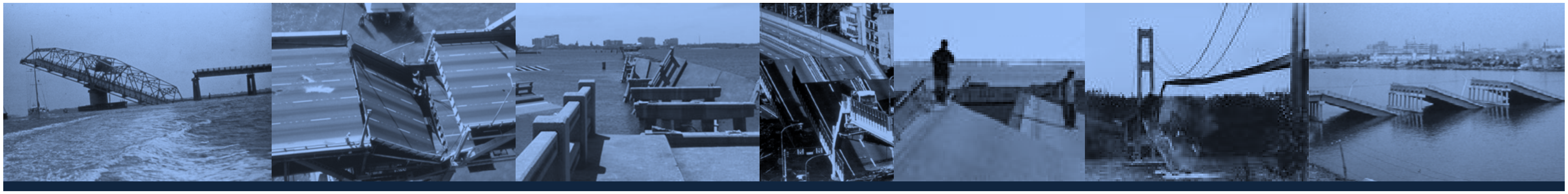

Isolation System for Short and Medium Span Typical Bridges

CSRN
RCRP

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Workshop on the Seismic Isolation and Damping of Bridge Structures
École Polytechnique – 26 May 2011

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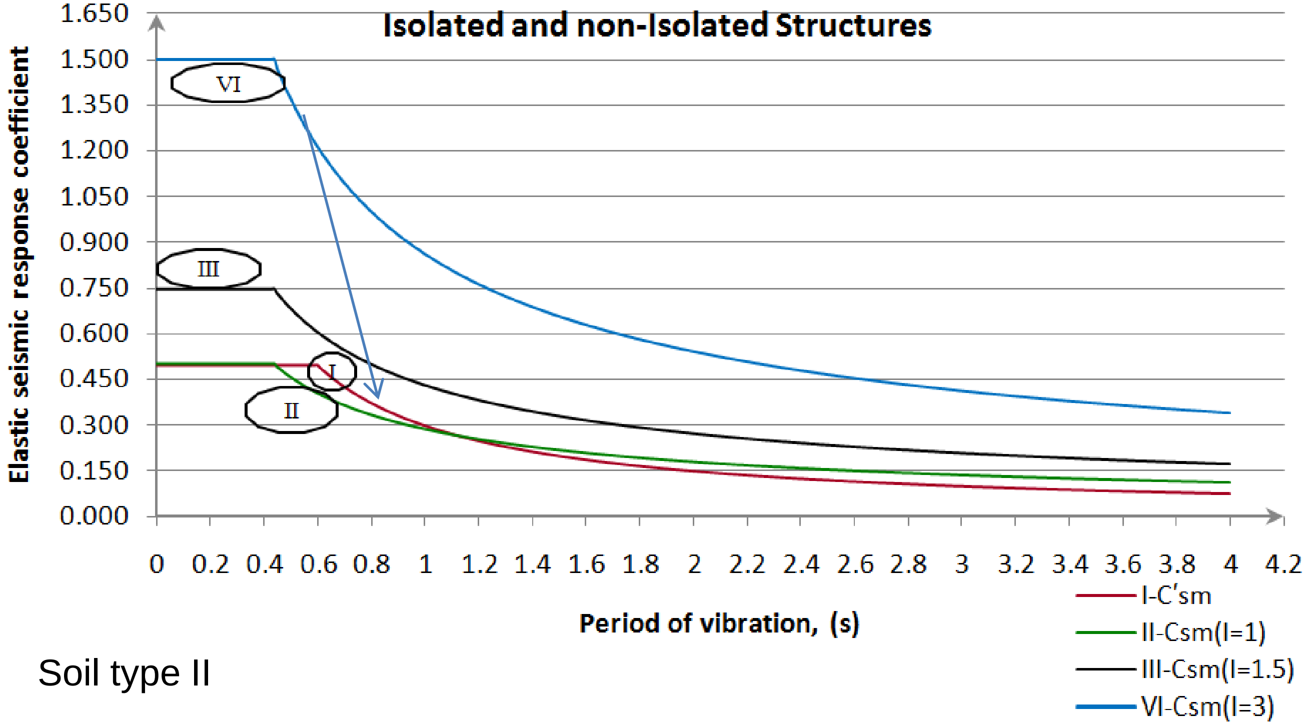
Isolation is interesting to reduce loads



$$C_{sm} = \frac{1,2AIS}{T_m^{2/3}} \leq 2,5AI$$

$$C'_{sm} = \frac{AS_i}{BT_e} \leq 2.5\frac{A}{B}$$

Soil type II

	S (non-isolated bridge)	S_i(isolated bridge)	S_i/S
I	**1.0**	**1.0**	**1.0**
II	**1.2**	**1.5**	**1.25**
III	**1.5**	**2.0**	**1.33**
IV	**2.0**	**2.7**	**1.35**

Additional interest of isolation for retrofit

- Routine change of bearings, expansion joints and slab are often missed opportunity to increase seismic capacity of a bridge
- Often isolation cannot bring a bridge back to code for high seismic zone, but in moderate seismic zone, many bridge can be brought back to code, or close too, at a small premium when bearing are planned to be changed.
- Isolation limit post earthquake damages.
- Isolation reduce seismic load and therefore may not result in expensive foundation retrofit.
- Isolation may require expensive devices, but often, simple elastomeric bearings can be used as isolators. Elastomeric bearing use as isolators are generally more expensive than non isolation elastomeric bearing but still less expansive than more complex devices.
- Elastomeric bearings are used routinely as isolators in Europe and in the US, but Canadians, for example in Quebec are still reluctant to use isolators.

➢ In order to investigate the interest of elastomeric bearing for bridge seismic retrofit, a parametric study is presented,

➢ Followed by some practical information on implementation in codes.

➢ The potential evolution of S6 for isolation is discussed

Parametric Study

- Importance factor: I = 1.0 , 1.5 , 3.0
- Span length: 20, 35 and 50 m
- Stiffness of the pier:
  - 25,000 kN/m (corresponding to a multi-bent with 2 columns 1.2m in diameter and 5.5-m in height)
  - 100,000 kN/m (2 columns 1.5-m in diameter with about 6m in height), and
  - 250,000 kN/m (corresponding to a wall 1.2m in thickness and 6-m long and 6m in height)
- The dead weight of the bridge:
  - 50 kN/m (Typical of a light steel girder with a concrete slab),
  - 100 kN/m (typical of a heavy steel girder or a light concrete girder) and
  - 200 kN/m (typical of a heavy concrete girder solution)
- R-factor: R=3.0 or R=5.0

Design Assumptions

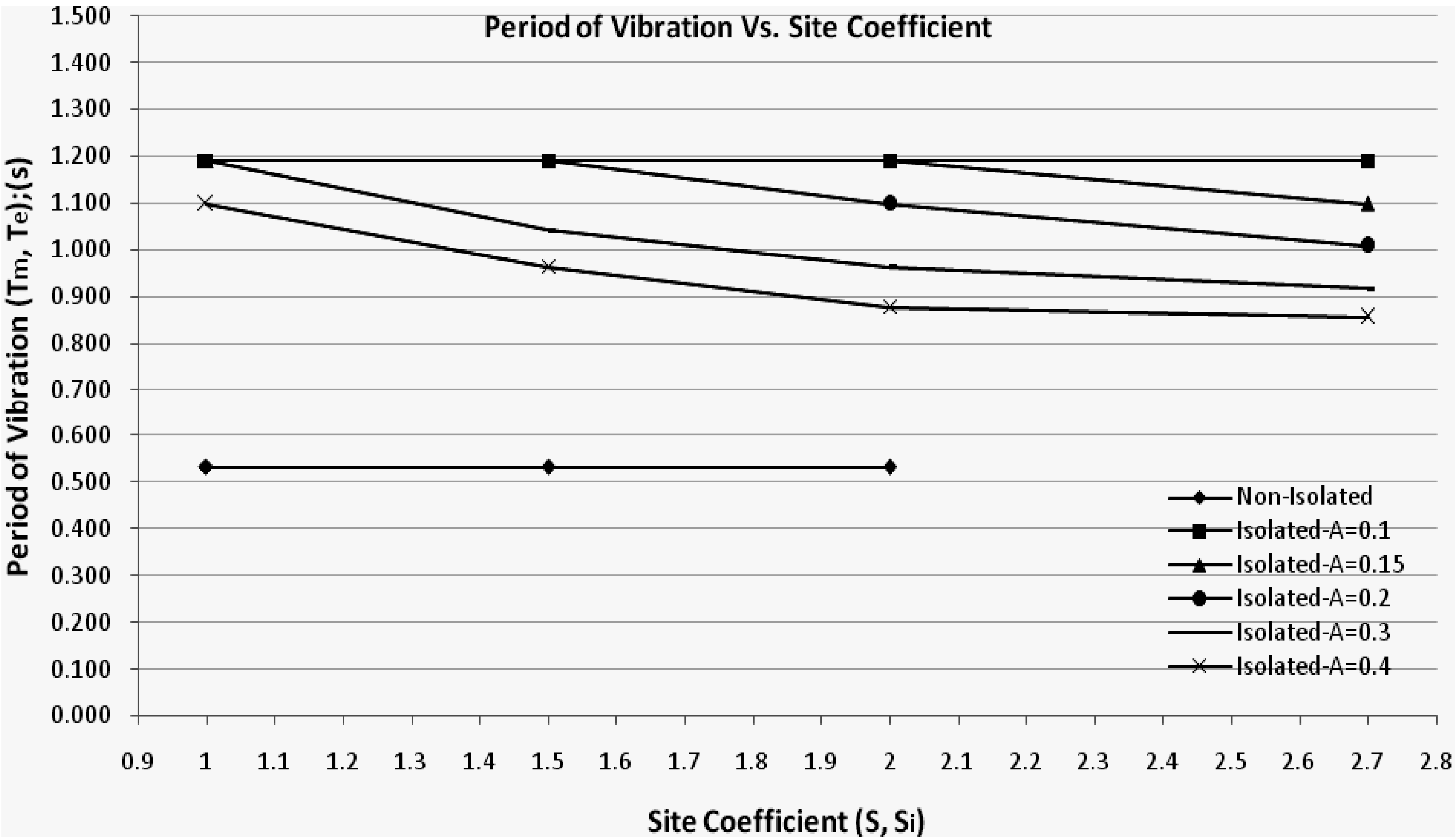
A full design is conducted for the bearings. In order to simplify the analysis the following assumptions are used:

- S6-06 load cases are used as well as CL-625 and CL-625w.
  - Reaction under dead loads are assumed identical for each bearing of a line of bearing.
  - For live load, simplified method as per S6-06 Chap 5.7 is used
  - Seismic loads are calculated assuming the bridge to be a rigid solid
- The design of the elastomeric bearing is carried as follows:
  - In-plan size of the bearing determined with the dead and live load combination at serviceability and at ultimate limit state
  - The thickness of the bearing is limited to 1/5. S6-06 limits the value to 1/3 but this may result in insufficient buckling strength during tests.
  - considers a limit distorsion of 1. A higher distorsion is often available, but need to be confirmed by tests.

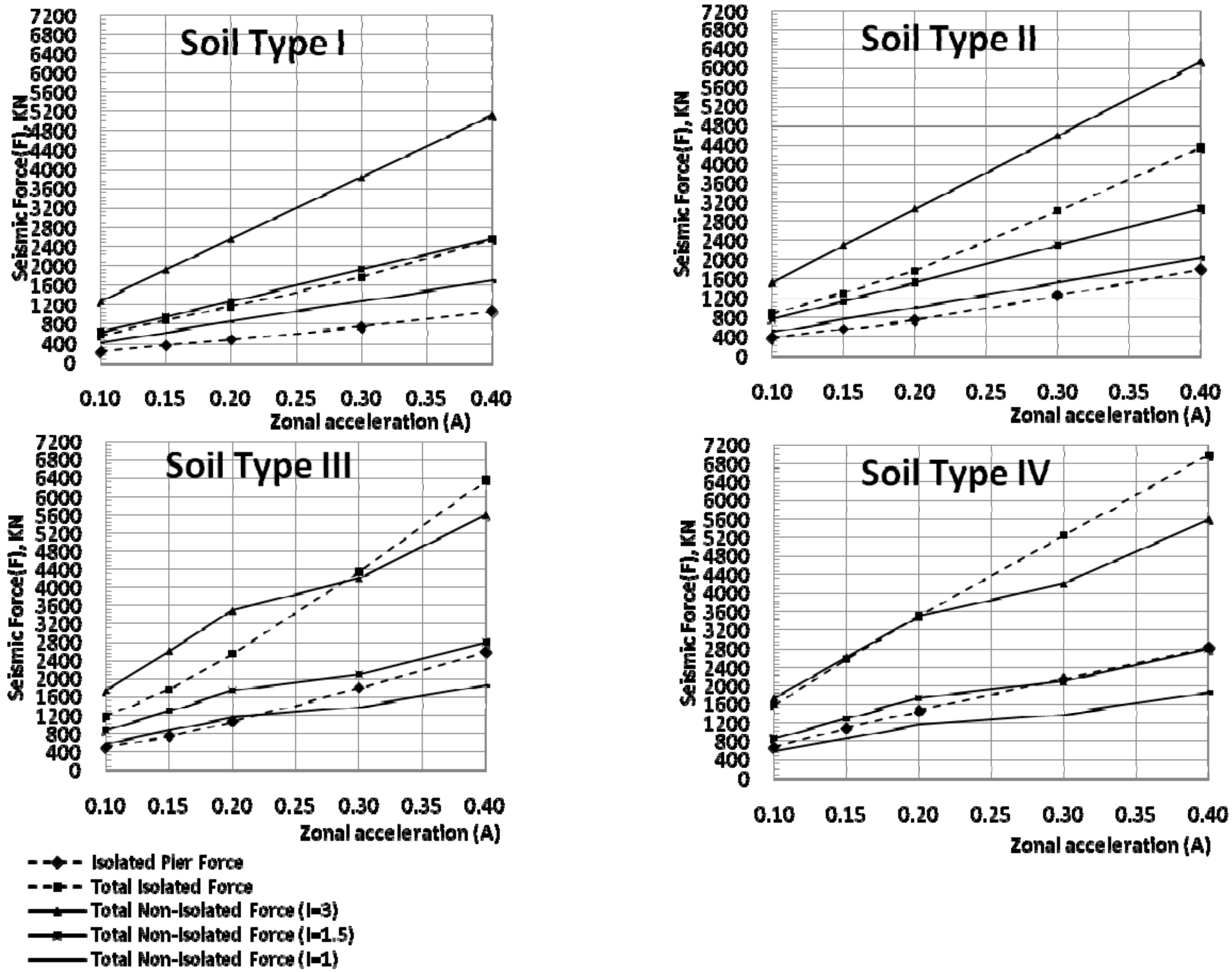
Bearing Size

		L=35 ; K=100 ; W=100		L=35 ; K=25 ; W=100		L=35 ; K=250 ; W=100	
	Soil Type	Abutment	Bent	Abutment	Bent	Abutment	Bent
A=0.1	**I**	286x57	461x92				
	II	286x57	461x92	286x57	461x92	286x57	461x92
	III	286x57	461x92				
	IV	286x57	461x92				
A=0.15	**I**	286x57	461x92				
	II	286x57	461x92	286x57	461x92	286x57	461x92
	III	286x57	461x92				
	IV	338x68	545x109				
A=0.2	**I**	286x57	461x92				
	II	286x57	461x92	286x57	461x92	286x57	461x92
	III	338x68	545x109				
	IV	404x81	652x130				
A=0.3	**I**	286x57	461x92				
	II	378x76	609x122	378x76	609x122	367x73	609x122
	III	444x89	716x143				
	IV	494x99	795x150				
A=0.4	**I**	338x68	545x109				
	II	444x89	716x143	469x94	756x151	444x89	716x143
	III	542x108	873x175				
	IV	572x114	921x184				

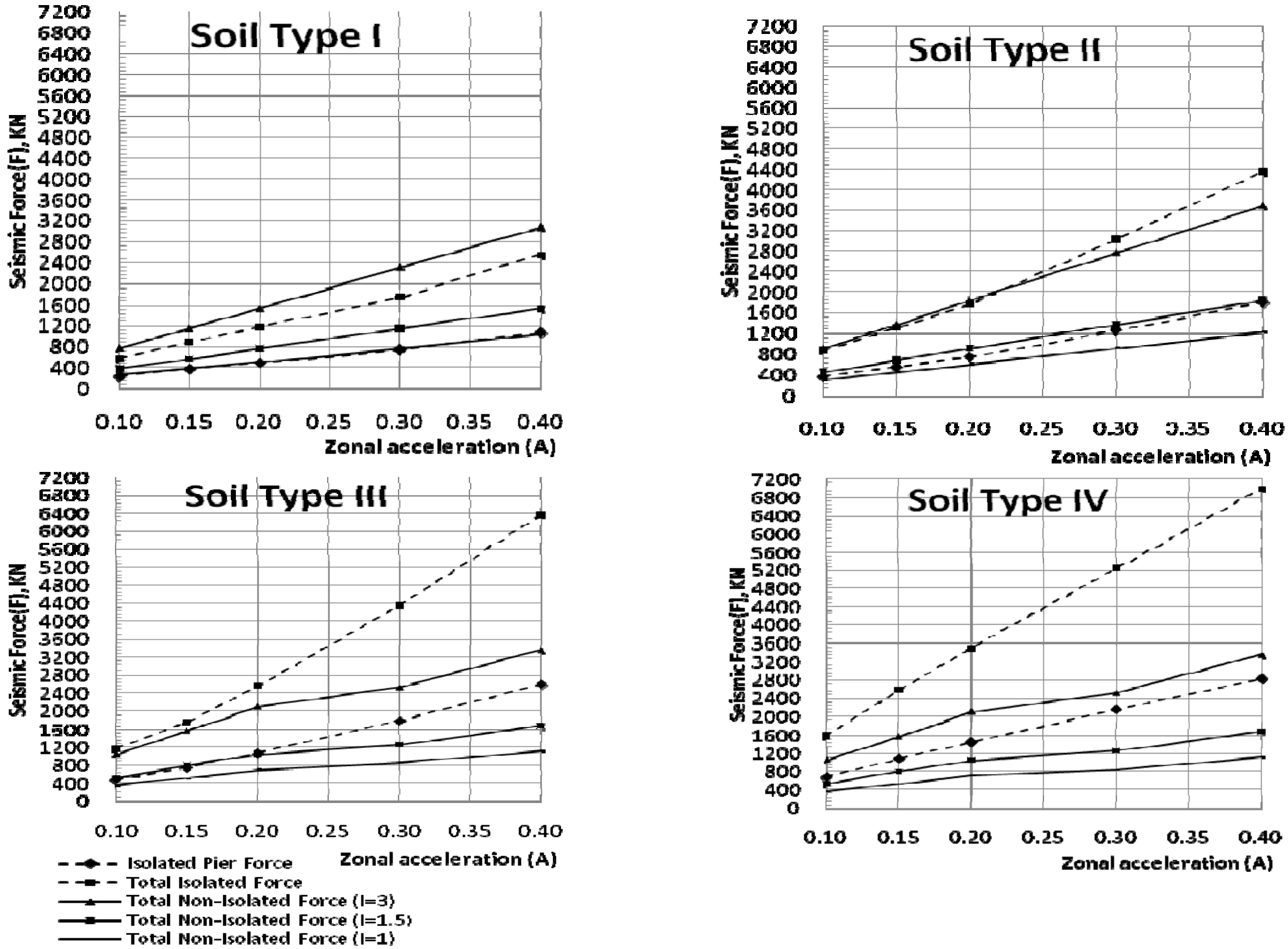
Evolution of period



L = 35m; K = 100 MN/m ; w = 100kN/m ; and R=3

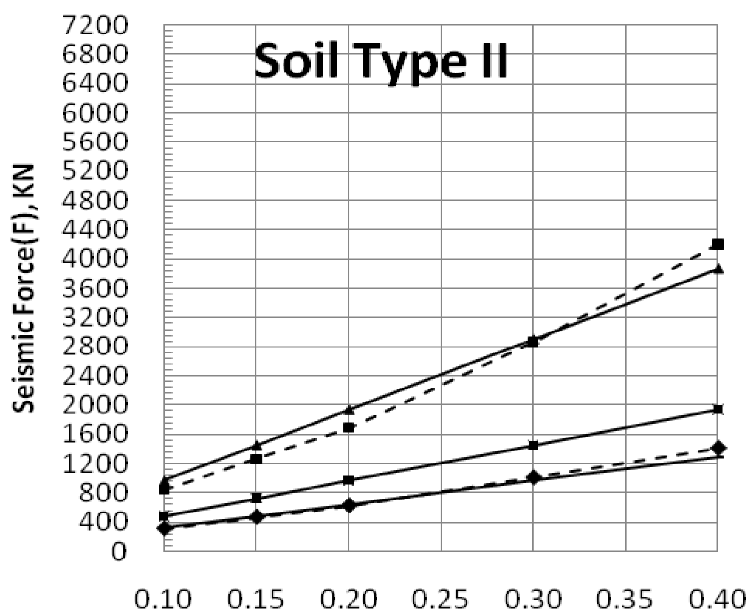


L = 35m; K = 100 MN/m ; w = 100kN/m ; and R=5

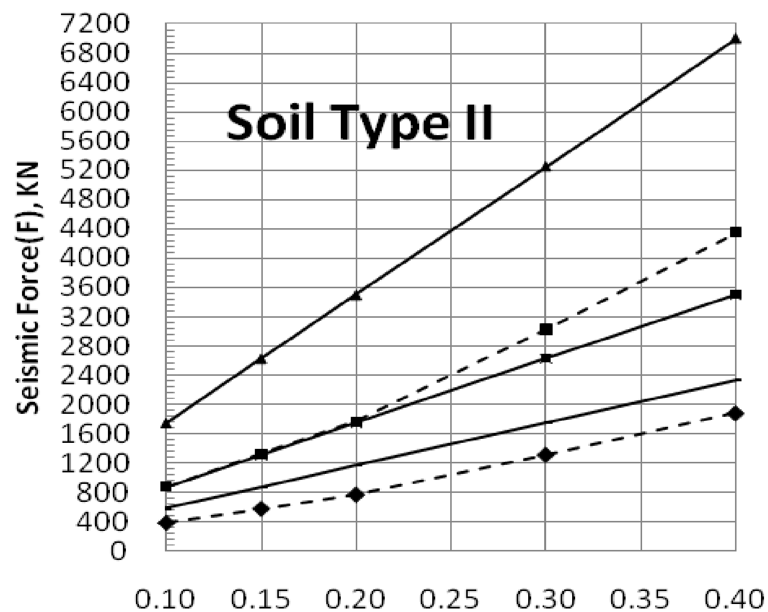


L = 35m; w = 100kN/m ; and R=3

K=25 MN/m

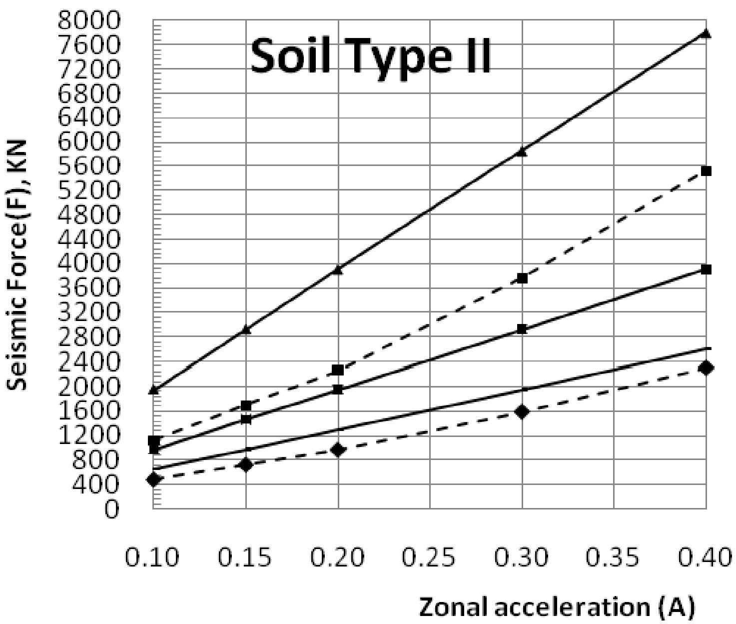


K=250 MN/m

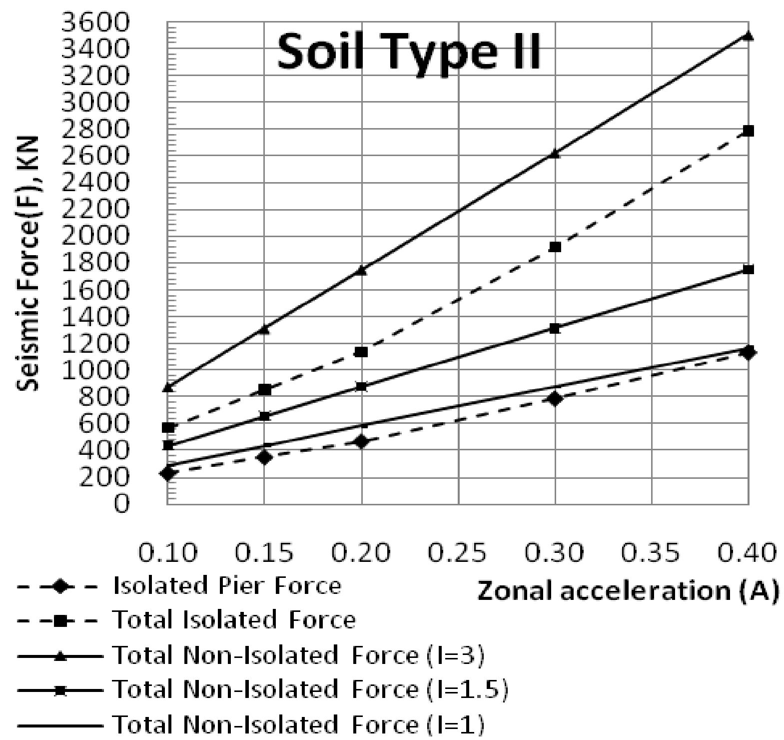


L = 50m; K=100 MN/m; and R=3

w=100 kN/m



w=50 kN/m

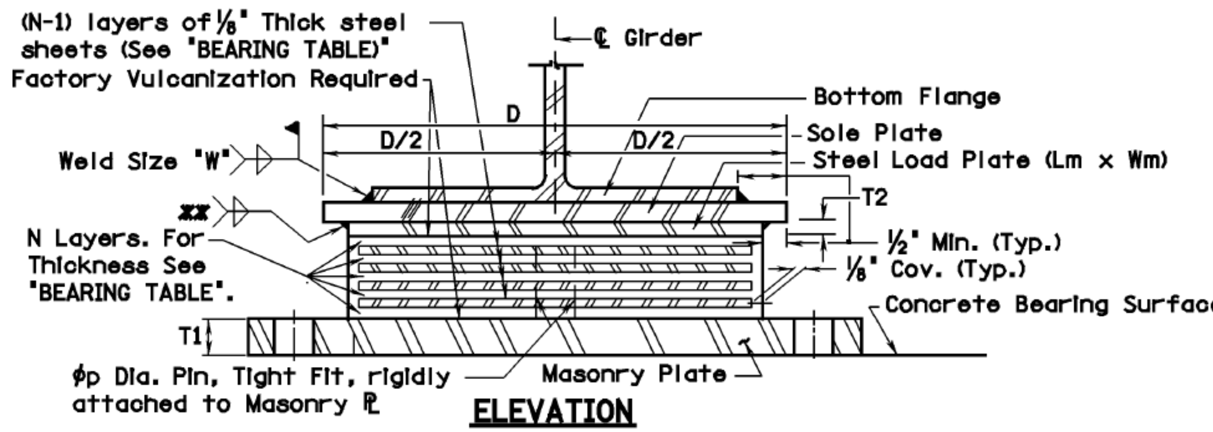


Some Practical Aspects

- Often, isolation with elastomeric bearing is considered too esoteric by designer whereas it simplifies bridge behavior under an earthquake in a number of cases (irregular bridges).
- Elastomeric bearings can reduce significantly the demand on substructure and this is very interesting for seismic retrofitting of existing structures
- Owners usually do not like floating systems as it has resulted in many durability issues in the past:
  - ➢ It is possible to use a fixed system with a fuse type system so for service there is a standard bearing condition (one fixed bearing for the 2-span example) and under seismic, the link is broken. It is even possible to use energy dissipating device to reduce seismic displacements.
- Elimination of importance factor in the design of elastomeric bearing design is a divisive question:
  - ➢ Principle in code request the bridge to withstand earthquake of 1000-yr return period with minor or very minor damage for emergency and lifeline bridge. It is questionable if design for 475-yr return period for lifeline bridge will ensure this performance.
  - ➢ By comparison to standard bridge design, use of I=1 and R=1 for capacity protected elements tend to assume that S6-06 consider that use of I=1 and R=1 ensure resistance of capacity protected members to 1000-year return period.
  - ➢ Recommendation of the author is to design for 1000-yr return period earthquake for lifeline bridges at least, but this should be addressed properly in revision of Section 4.10.

Some Practical Aspects

- Elastomeric bearings shall carry horizontal loads during an earthquake. Typically bearing/concrete surface cannot provide enough friction. Vulcanized plates can be used in this case.



From NJ DOT structure manual

- Test are usually required before construction to validate the design of the bearing. These test add to the overall schedule. Those tests usually offer few surprises.
- Those projects often being fast tracked, it would be practical if researchers, practitioners and fabricators pool their resources together in order to provide a comprehensive design specification comparable to other specification in the world so elastomeric bearing would not require any test for most projects.

Some Practical Aspects

- Elastomeric bearing used as isolators are usually taller than comparable elastomeric bearing not designed as isolators:
  - Impact on road profile right at the beginning of the project. This is particularly important for retrofit projects.
- Elastomeric bearing request more displacement capacity for the bridge than standard structures:
  - Bridge needs to accommodate for these displacement without pounding into abutment or pier diaphragms.
- Use of CNB2005 is tempting in the east coast and for isolation bearing. Often short period acceleration is higher in CNB2005 than in S6-06, but design spectra of CNB2005 drops sharply for long periods which is very interesting for isolation but may lead to unrealistic displacement demand.

Conclusion and Recommendations

- Elastomeric bearings are interesting solution for retrofitting of bridges by reducing demand on existing substructure
- Partial retrofit is usually available with a small premium as compared to a normal change of bearings
- A number of practical solutions exist to use elastomeric bearings as isolators for retrofitting projects.
- Elastomeric bearings seem also interesting for new projects where I = 1.5 and I =3.0. In addition, for lifeline project, use of isolation may result in no damages even for very strong earthquakes
- Better design method should be provided in order to reduce cost, risk and project delays.

Ongoing research

- Displacement demand may lead to very flexible bearings which may be expansive and do not perform well in service and require large support length and expansion joints.
  - ➢ We are looking at combination of elastomeric bearings and dampers to reduce displacement demand.
- What behaviour should be considering for the RC members: what level of ductility?
  - ➢ Fragility curves are being developed to provide some guidance to what is the necessary level of ductility
- Refinement in analysis method: how can we select the most effective method for analysing a structure with local dampers and isolators.
  - ➢ Case studies are used and comparison between different methods for simple typical structures.

Aknowledgement

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