1.054 Mechanics & Design of Concrete Structures

Seismic Isolation Using Passive Control Technologies

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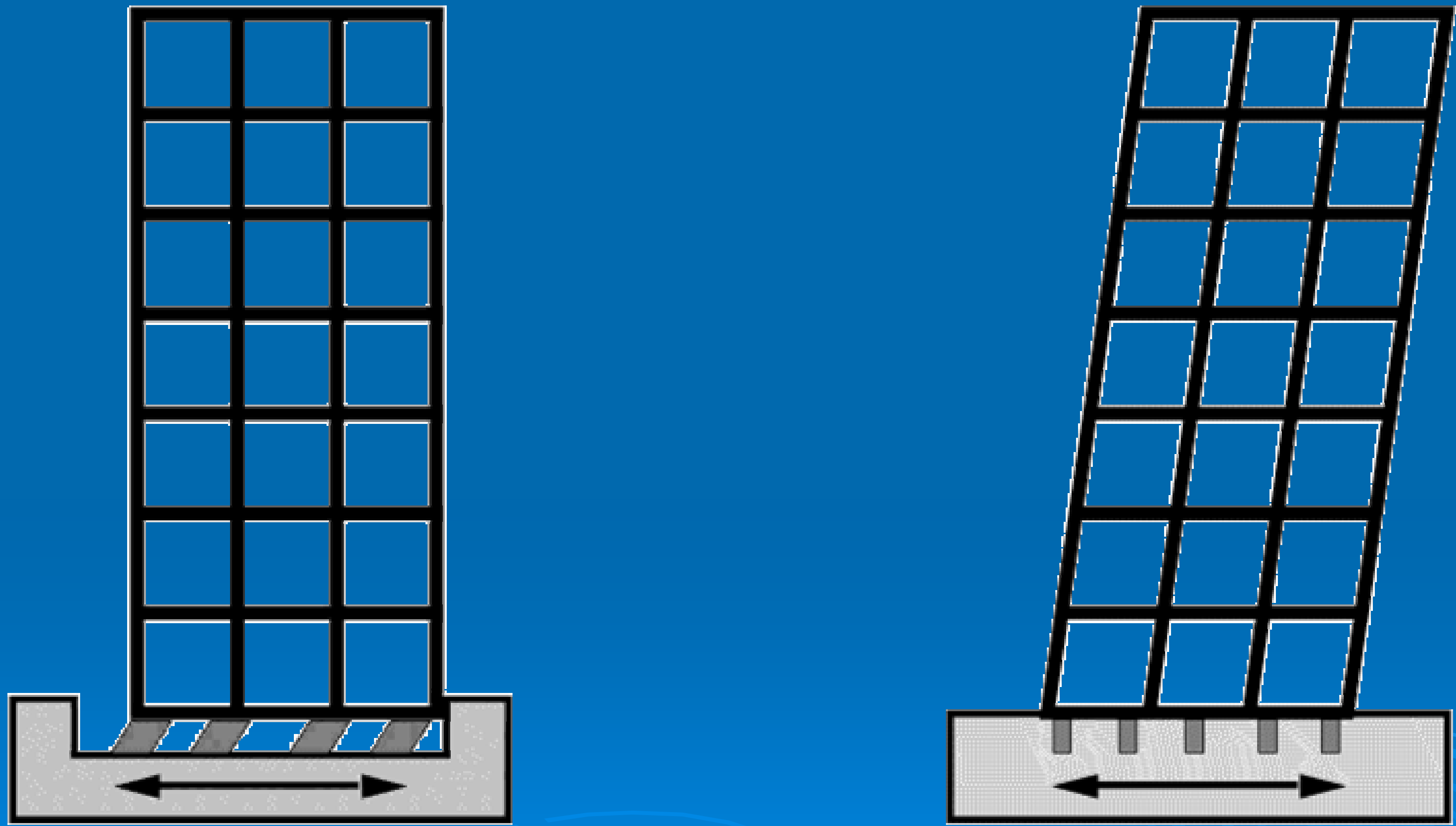
Isolated-Base vs Fixed Base



Seismic Isolation Using Passive Control Technologies

- Introduction
- Applications around the Globe
- Standards and Codes for Design
- Experimental results

Traditional Anti-Seismic Structure

- Allowing Struct. Elements or joints to work to dissipate the energy
- Not very safe
- Limited use
- Stronger elements -> Larger stiffness -> larger seismic load
- Stronger elements ->Higher Cost

Seismic Control

- Passive Control : no external power source
- Active Control : external power source

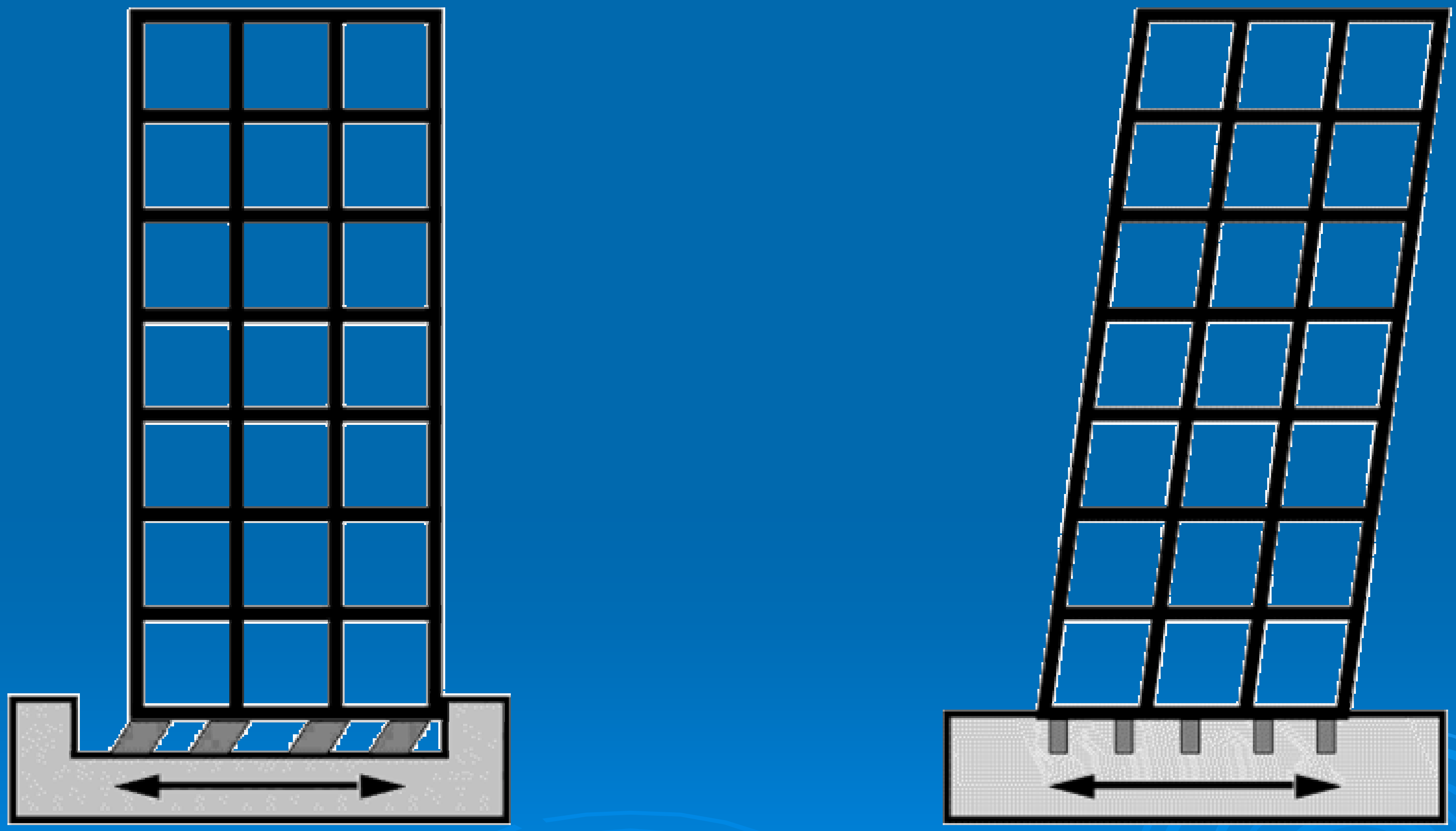
Types of Isolators

- 1-Sand Layer
- 2-Graphite-lime mortar layer
- 3-Sliding friction layer
- 4-Rollers
- 5-Rubber Bearings
- 1,2,3 are too sensitive to foundation settlement
- 4 need careful maintenance
- 5 most widely used : no moving parts, unaffected by time, resistant to environment

Isolator Role

- Reduce the response of the structure
- Installed between foundation & struct. Or relevant parts of structure
- Extend the natural period of the structure
- Acceleration response is reduced

Isolated-Base vs Fixed Base



Features

- Response can be reduced to 1/2 to 1/8
- Bldg costs can be reduced 3 to 15%
- Wide range of application : New and Old
- Freedom of architectural deisgn : can be used in bldgs with irregular configurations

Rubber Bearing

- Steel and Rubber sheets

Rubber Bearing

- Steel, Rubber, and Lead Core

Rubber Bearing Features

- Effective isolation, ½ to1/8 tradit.response
- Stable no maintenance lifetime >100 years
- They recover from displacement perfectly
- Can accommodate vertical motion of bldg
- Insensitivity to foundation settlement
- They have operated successfully USA,China, Japan
- They decrease temperature stress in structures by horiz. deform. During large change of T°

US Applications

- 1994 Northridge EQ
- USC Hospital 8 stories
- supported on 68 lead rubber isolators and 81 elastomeric isolators
- The PGA outside the building was 0.49 g, and the accelerations inside the building were around 0.10 to 0.13 g.

JAPAN Applications

- largest base-isolated building in the world

- West Japan Postal Computer Center, Kobe
- This six-storey, (500,000 ft square) structure
- Supported on 120 elastomeric isolators isolated
- Isolated period of 3.9 sec
- PGA = 0.41 g
- Reduced by the isolation system to (0.13 g) at 6th floor.

ARMENIA Applications

Design & Cost Comparison of 4 storey building

Values compared	Fixed-base building	Seismically isolated building
Total shear fore (kN)	40800	10200
Required reinforcement (t)	360	104
Required reinforcement per 1 m^2 of the area of the building (kg)	110	32
Distance (cm) between the reinforcing bars and their average diameter (mm) in the walls	20×20, ∅16	40×40, ∅8
Required strength of the concrete (N/cm^2)	2500	1500
Required cement (t)	810	428
Required cement per 1 m^2 of the area of the building (kg)	250	132
Cost of reinforcement (US$)	144000	41600
Cost of cement (US$)	32210	17550
Cost of seismic isolators (US$)		24700

Savings = (144,000+32,210) – (41,600+17,550+24,700) = $92,360
Cost of bearing structure = $ 27,000

Total Savings = $ 65,360 = 30% Savings

NEW ZEALAND Application

- Museum of NZ Te Papa , Wellington
- Heaviest seismically isolated in the world
- 190 x 104 m, , 23 m height
- 5 storey , 35000 sq m
- Required to Suffer no damage in 250 years !!!
- No collapse with a 2000 years earthquake
- 142 lead rubber bearings , with Teflon slidings under shear walls

NEW ZEALAND Application

	250 year	2000 year
Isolated Max floor accel.	0.33 g	0.48 g
Fixed base max. floor accel	1.02 g	1.69 g
Displacement-Isolated	260 mm	510 mm

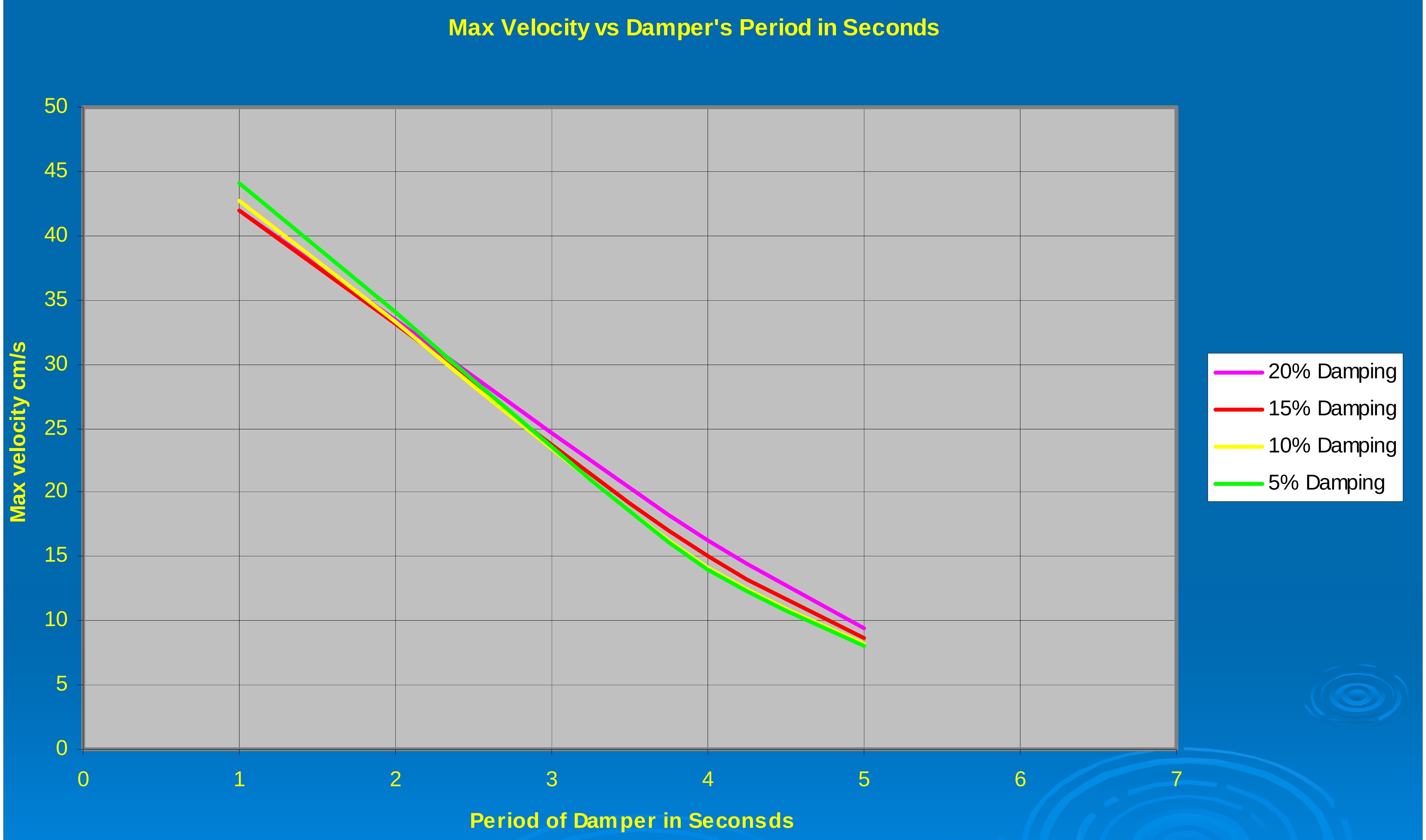
Period of isolated structure = 2.5 s

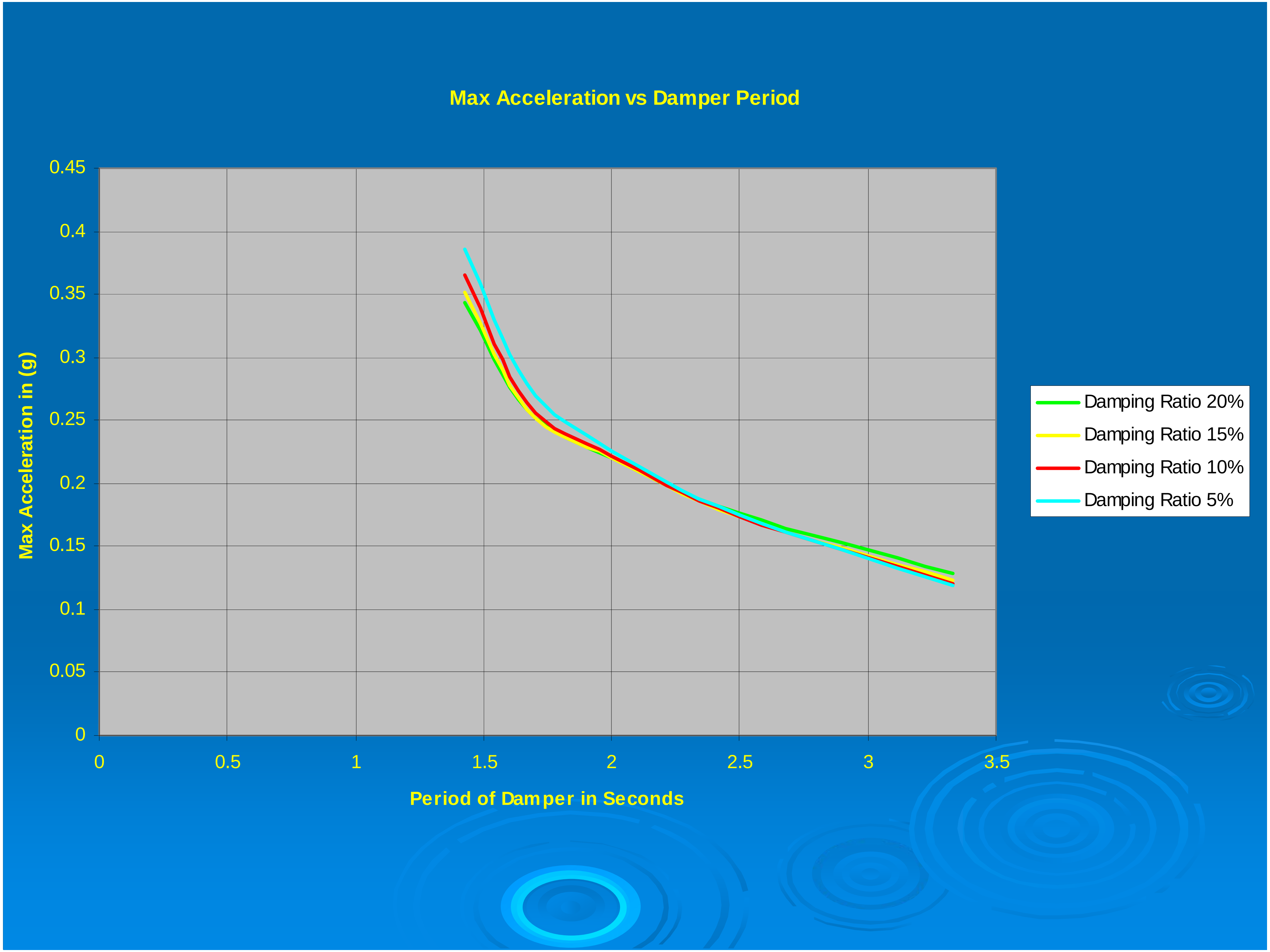
NEW ZEALAND Application

Results of Feasibility study on damage costs to content and structure
Museum of NZ Te Papa

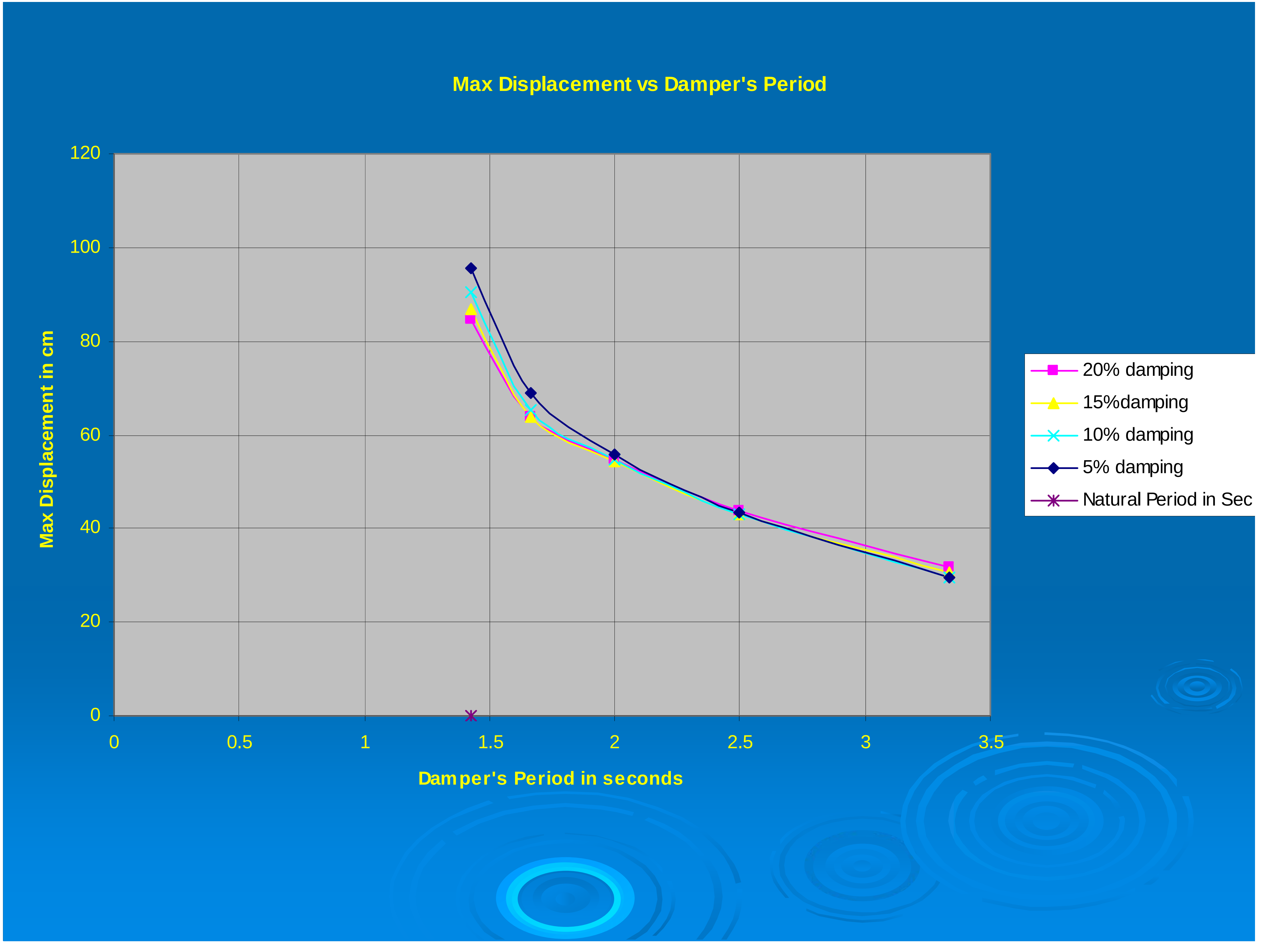
Simulation

- We used a Java powered simulation program developed by Prof.B.F Spencer Jr. from the UIUC
- a SDOF (single degree of freedom) frame
- Structure : 100 tons , 1 Hz, damping ratio is 5%.
- Isolation system : mass ratio (mass of base slab divided by mass of superstructure) is 0.10 ,
- natural frequency 0.5 Hz,
- the damping ratio will be varied between 5 and 20%
- Frequency will be varied between 0.7 Hz and 0.3Hz
- El Centro Earthquake


Max Velocity vs Damper's Period in Seconds
Max velocity cm/s
Period of Damper in Seconsds
50
45
40
35
30
25
20
15
10
5
0
0
1
2
3
4
5
6
7
20% Damping
15% Damping
10% Damping
5% Damping



Max Acceleration vs Damper Period
Max Acceleration in (g)
0.45
0.4
0.35
0.3
0.25
0.2
0.15
0.1
0.05
0
0
0.5
1
1.5
2
2.5
3
3.5
Period of Damper in Seconds
Damping Ratio 20%
Damping Ratio 15%
Damping Ratio 10%
Damping Ratio 5%



Max Displacement vs Damper's Period
120
100
80
60
40
20
0
0
0.5
1
1.5
2
2.5
3
3.5
Max Displacement in cm
Damper's Period in seconds
20% damping
15%damping
10% damping
5% damping
Natural Period in Sec

frequency (Hz)	0.7	0.6	0.5	0.4	0.3	Damping
period (sec)	1.43	1.67	2.00	2.50	3.33	
Max.displacement	84.8	63.8	54.7	43.9	31.8	20%
mm						
	86.9	64	54.4	43.1	30.6	15%
	90.4	65.3	54.8	42.9	29.7	10%
	95.6	69.1	55.9	43.5	29.6	5%
Max Velocity	41.89	33.39	24.57	16.22	9.37	20%
cm/s						
	42.01	33.06	23.73	15	8.65	15%
	42.69	33.21	23.35	14.13	8.15	10%
	44.06	34.01	23.49	14.01	8.05	5%
Max Acceleration	0.343	0.258	0.221	0.177	0.129	20%
g						
	0.351	0.259	0.220	0.174	0.123	15%
	0.365	0.264	0.221	0.173	0.120	10%
	0.386	0.279	0.226	0.176	0.119	5%

Interpretation-1

Maximum Displacement

Fixed Base	745.1 mm
Isolated	95.6 mm
Reduction	8 times

Interpretation-2

Maximum Velocity

- Fixed Base 467.26 cm/s
- Isolated 44.06 cm/s
- Reduction 10 times

Interpretation-3

Maximum Acceleration

- Fixed Base 3.0157 g
- Isolated 0.386 g
- Reduction 8 times

Interpretation

- Reduction up to 8 times in the acceleration, velocity and displacement

- In accordance with the most optimistic results from literature review (case of China).

Conclusions

- Innovative technique to protect buildings
- Not widespread use
- Significant Cost and Risk Reductions
- Successful Real life examples (USC, Kobe)
- Standardization will improve proliferation
- Simulation results in accordance with literature conclusions

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