



# Buildings That Resist Earthquakes Better



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# KOBE, JAPAN 1995



- Magnitude 6.9
- 5,500 killed
- 26,000+ injured
- \$200 Billion in economic loss

# GOALS AND OBJECTIVES

- Compare and contrast the effects of a disturbance on a structure that has...
  - No damping device
  - Passive viscous damping
  - Base isolators
  - Active damping
- Determine if using actuators, sensors, and computers produce significantly better results

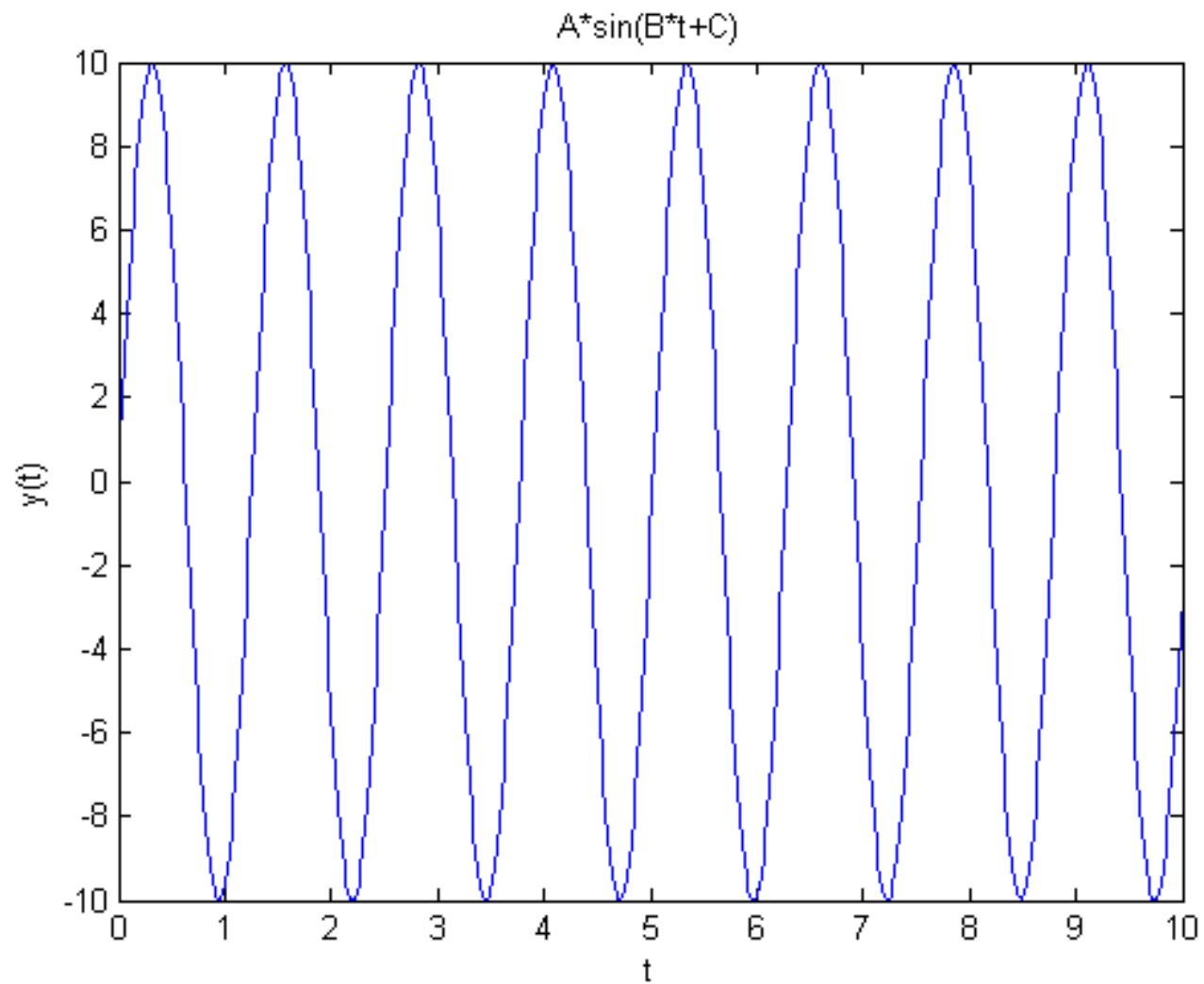
# STRUCTURAL DYNAMICS - VOCAB

- Stiffness ( $k$ ): force required to produce one unit of displacement
- Frequency ( $\omega/2\pi$ ): number of cycles per second
- Omega  $\omega = \sqrt{k/m}$ : movement along a circular frequency

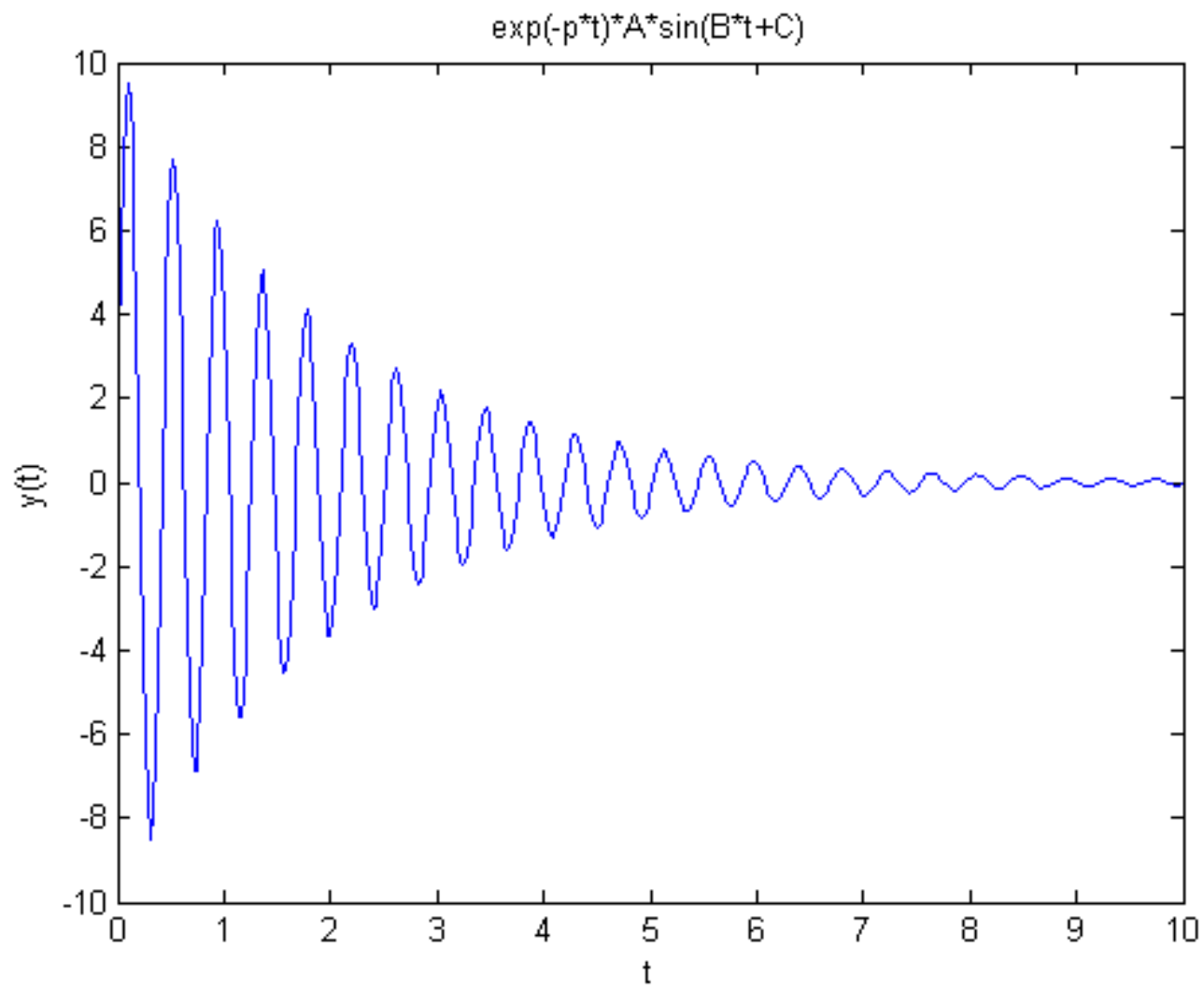
# STRUCTURAL DYNAMICS - VOCAB

- Damping (c): the rate of decrease of the amplitude with each successive cycle
- Resonance: If the frequency of the external dynamic forces = the frequency of the internal restoring forces, the building will collapse.

# UNDAMPED SYSTEM



# DAMPED SYSTEM

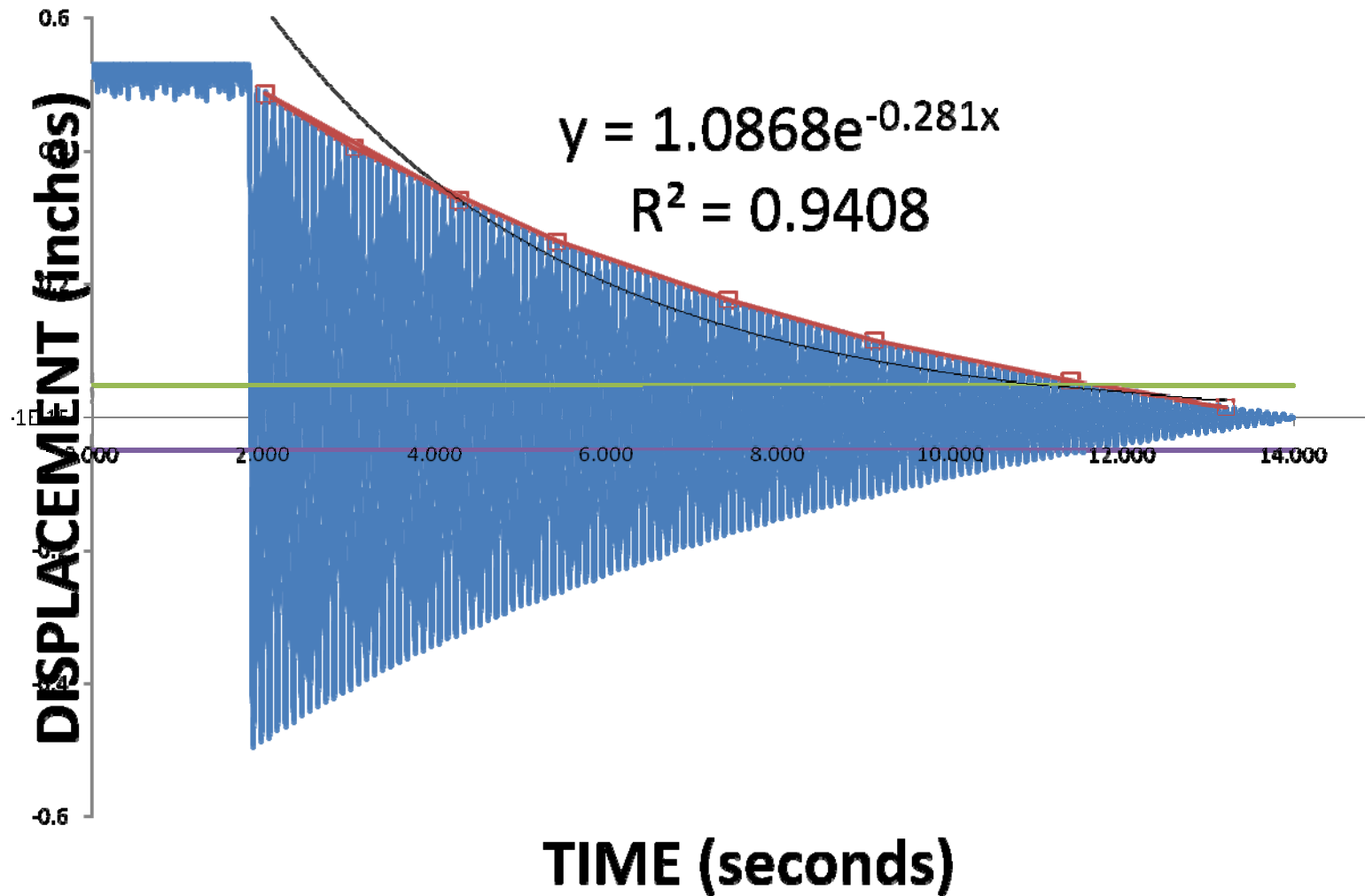


# NO DAMPING DEVICES

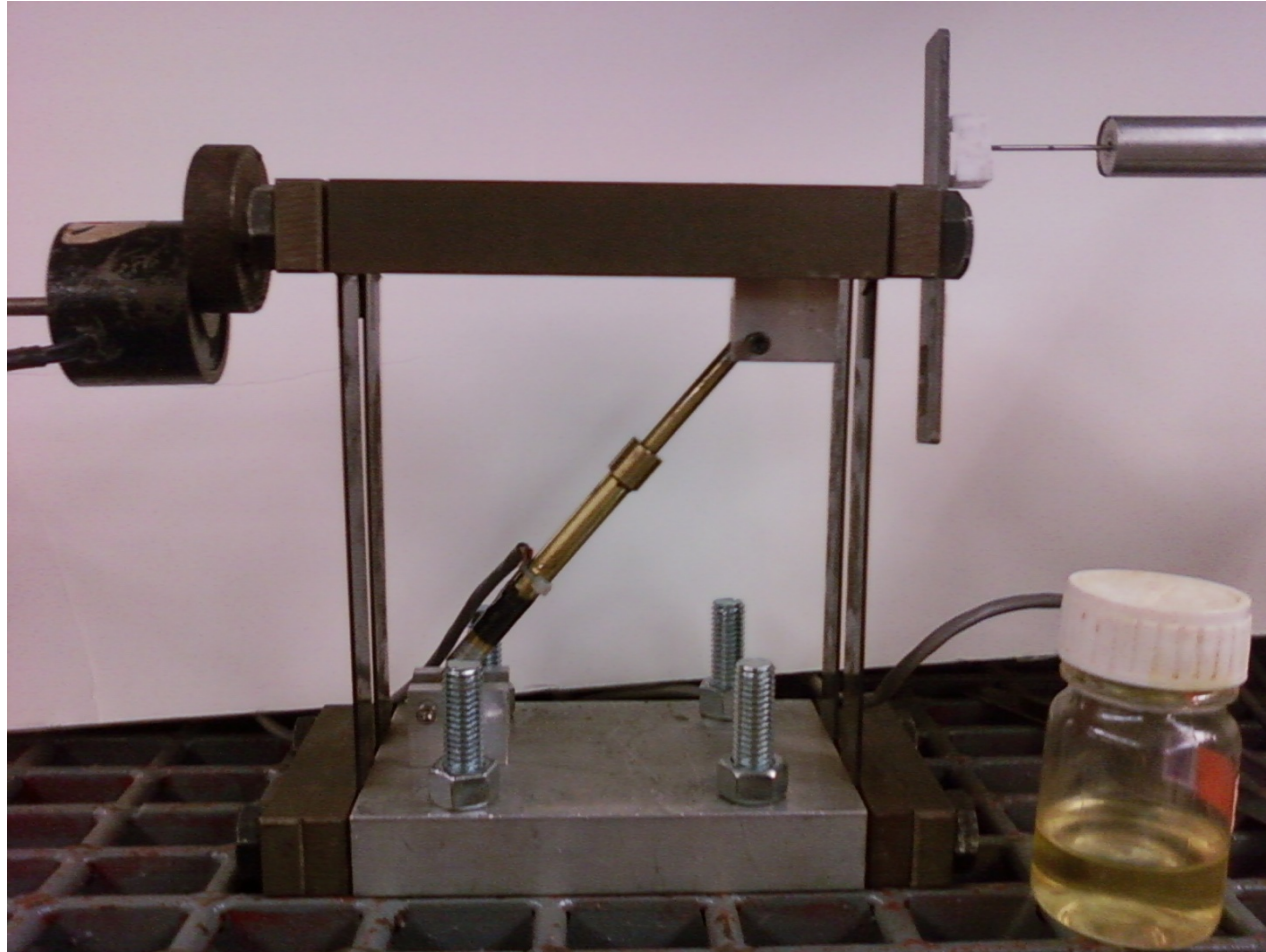


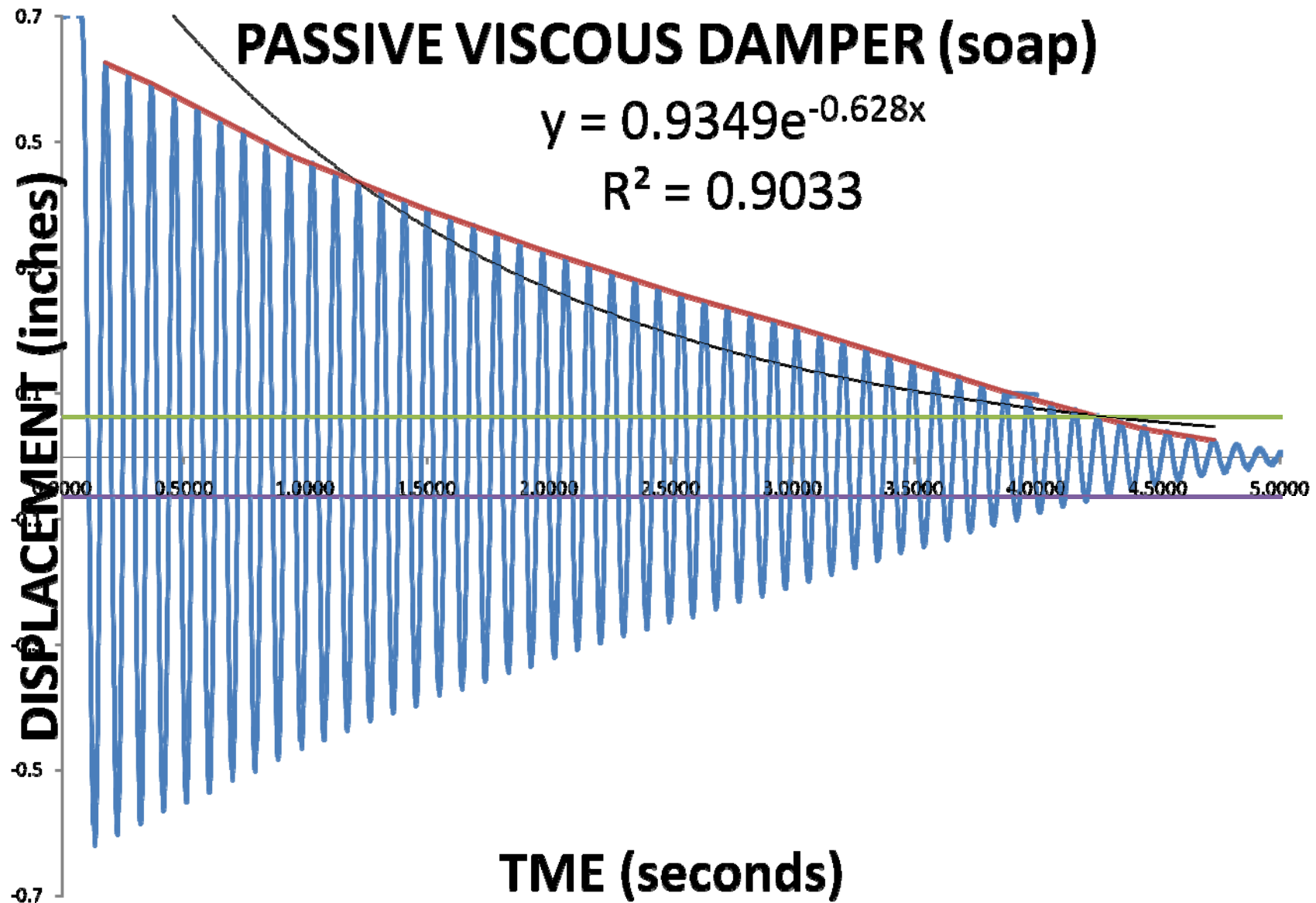


## NO DAMPING DEVICES

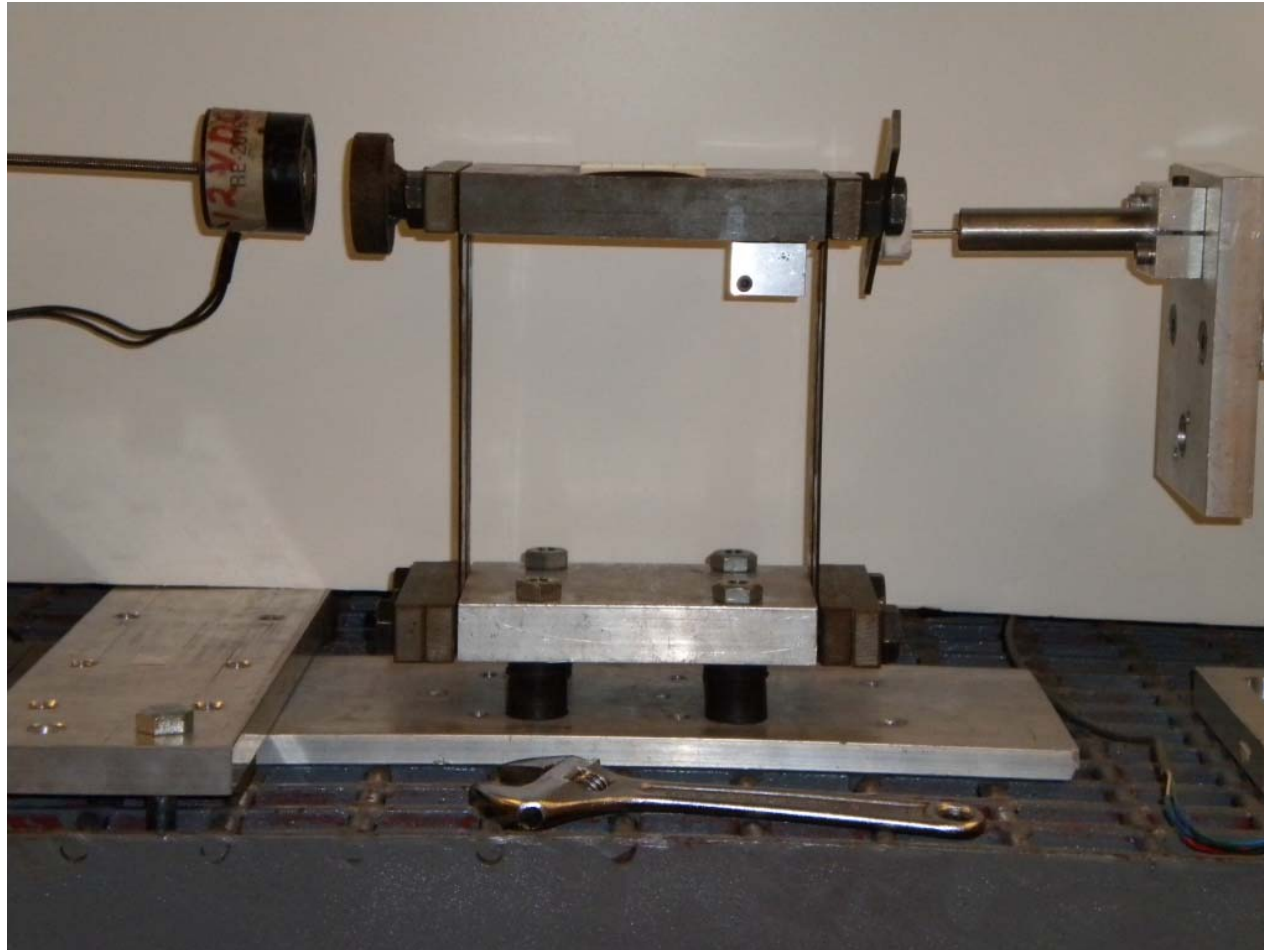


# PASSIVE VISCOUS DAMPING

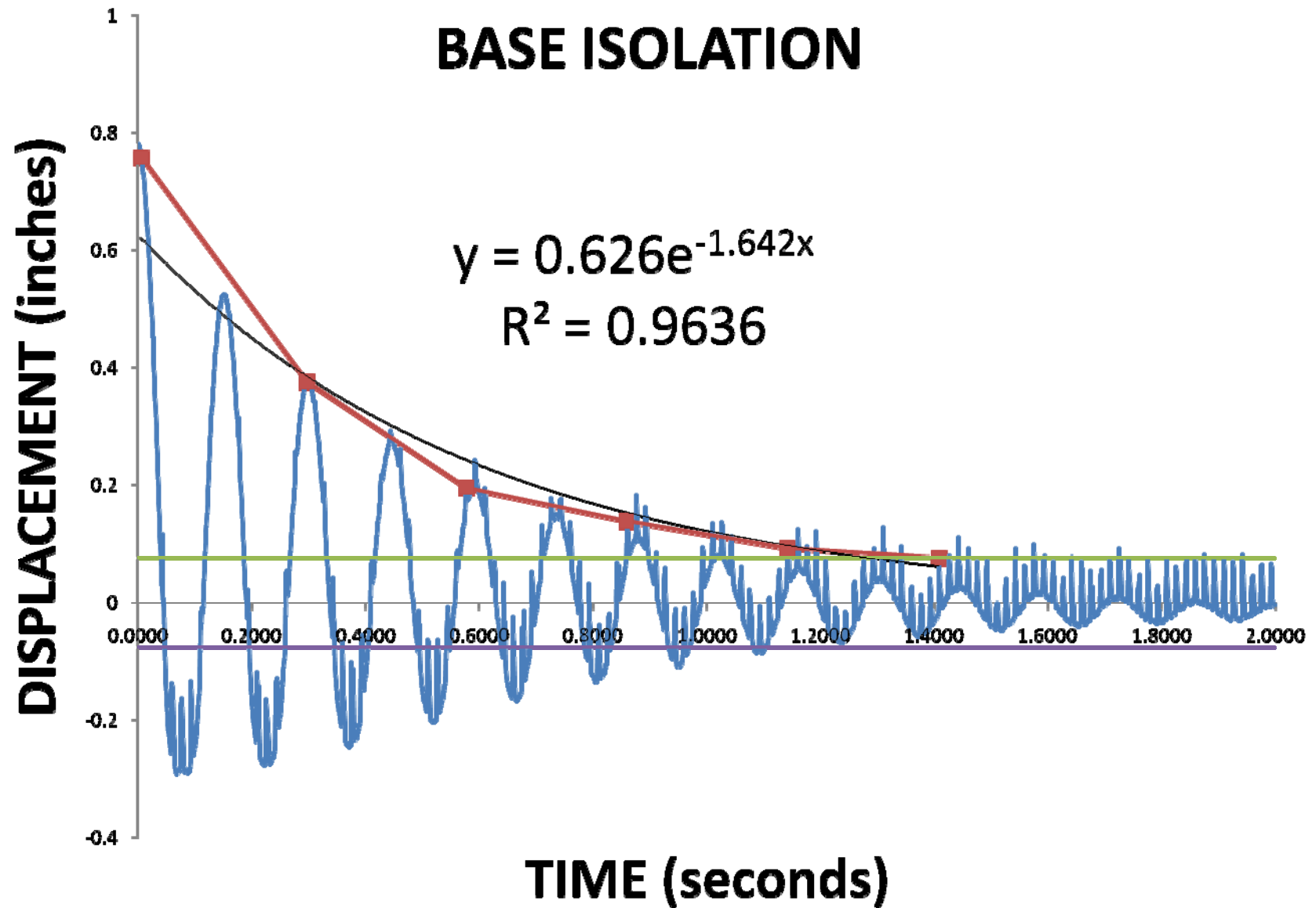




# BASE ISOLATORS



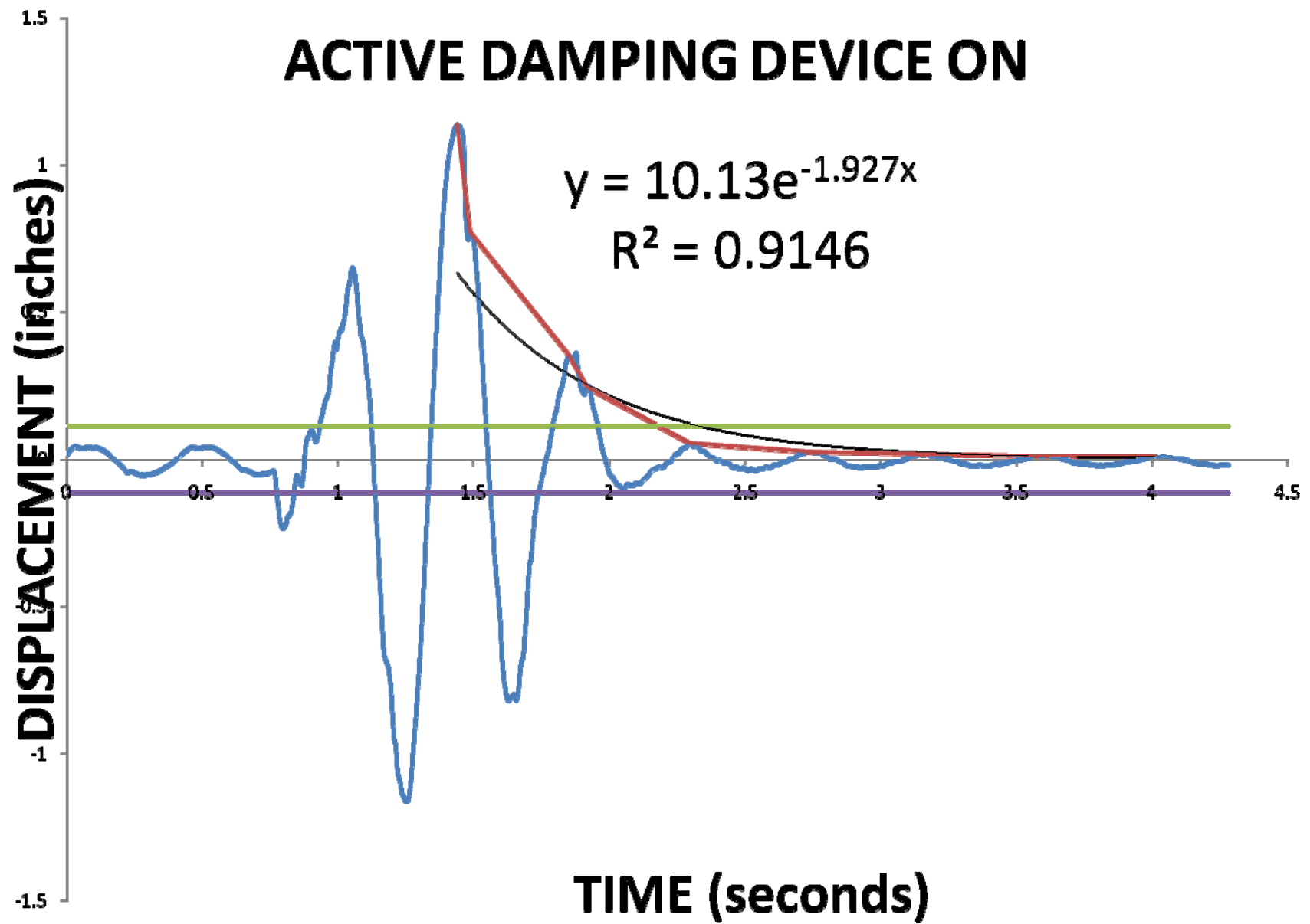
# BASE ISOLATION



# ACTIVE MASS DAMPER



## ACTIVE DAMPING DEVICE ON



# NEW VOCABULARY

Grant/ Rachel Speak	Actual Name	Symbol	Meaning
Snake with broken back	Zeta	$\zeta$	Damping coefficient
Omega sub n	Omega sub n	$\omega_n$	Natural frequency
Omega sub d	Omega sub d	$\omega_d$	Damped vibration frequency
Yellow ribbon	Gamma	$\gamma$	Coefficient in the exponential function. Also = $\zeta^* \omega_n$



## 2 EQUATIONS, 2 VARIABLES

$$\gamma = \zeta \omega_n$$

$$.271 = \zeta \omega_n$$

$$\omega_d = \omega_n \sqrt{1 - \zeta^2}$$

$$14.526 = \omega_n \sqrt{1 - \zeta^2}$$

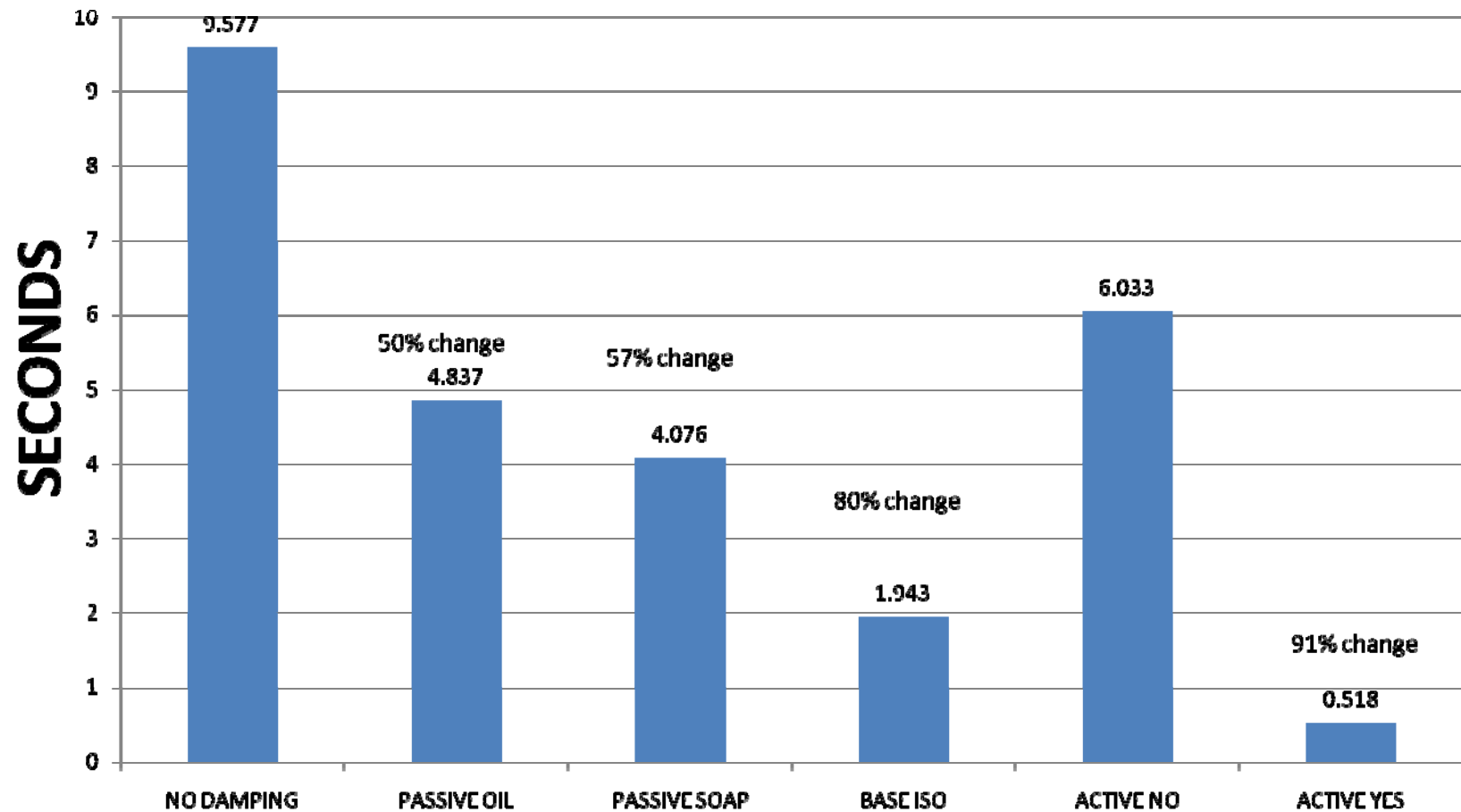
$$\omega_n = 15.53$$

$$\zeta = .02$$

# RESULTS

	Damping Coefficient	Circular Frequency (radians per second)
No Damping	.4%	66.84
Passive Damping (oil)	.8%	67.35
Passive Damping (soap)	.9%	66.65
Passive Base Isolators	3.7%	44.01
Active (damping off)	2.8%	15
Active (damping on)	13%	14.78

# SETTLING TIME



# CONCLUSIONS

- Active damping devices are the most effective means of protecting against earthquakes
- Active damping devices do seem to be worth the expense of actuators, sensors, and computers