18 ΦΟΙΤΗΤΙΚΟ ΣΥΝΕΔΡΙΟ
ΕΠΙΣΚΕΥΕΣ ΚΑΤΑΣΚΕΥΩΝ 2012
14-15 ΦΕΒΡΟΥΑΡΙΟΥ 2012

Δυναμική Ευστάθεια Αρθρωτών Κατασκευών

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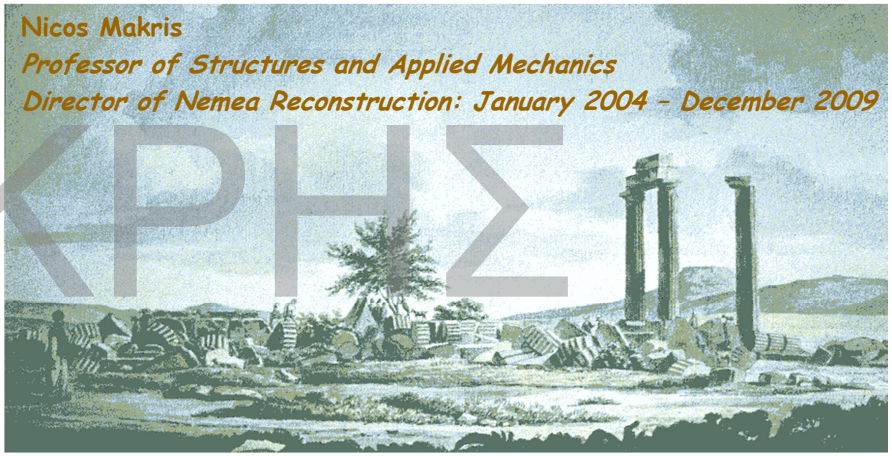
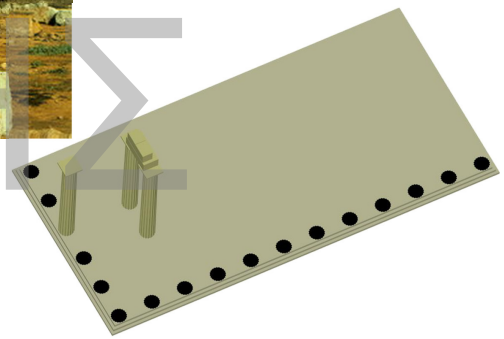
Τομέας Κατασκευών,Πανεπιστήμιο Πατρών

The Reconstruction of the North-East Corner of the Temple of Zeus at Nemea



Nemea – Temple of Zeus, 1766

View of the three columns standing from the ancient times

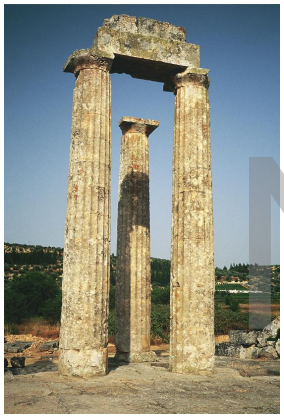


The challenge of reconstruction. Why reconstructing ?
Aerial View of the Temple (1977)

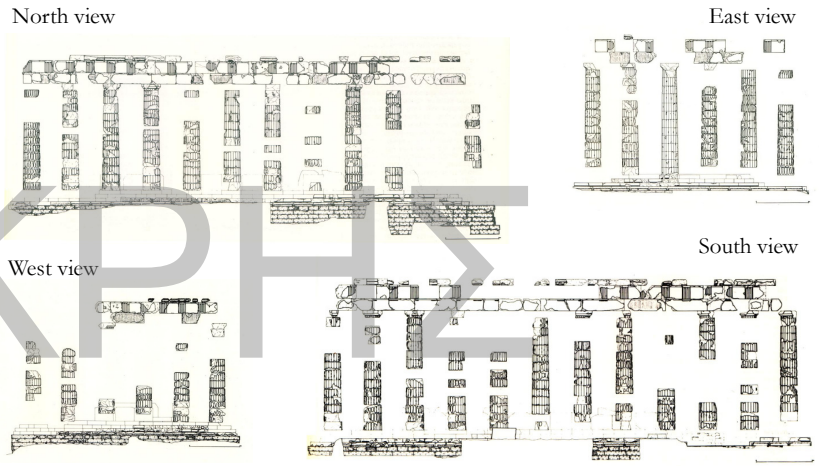
Columns have fallen to the outside

Erroded column drums

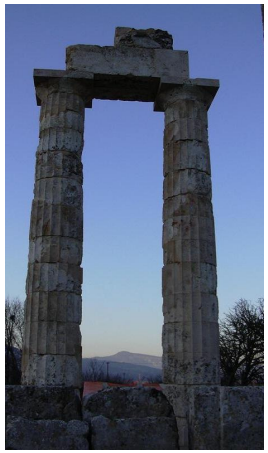
View from the west of the 3 standing columns from ancient times

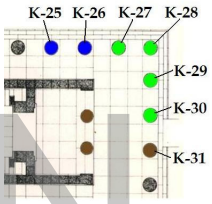


Synthesis of the ancient stone blocks by Frederic Cooper (1980-1982), University of Minnesota



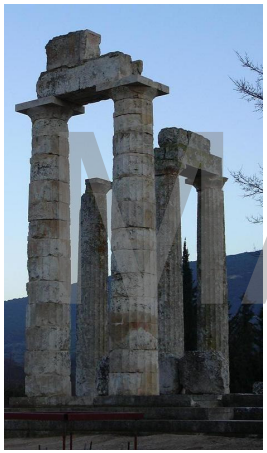
Pilot Reconstruction: columns K-25 & K-26



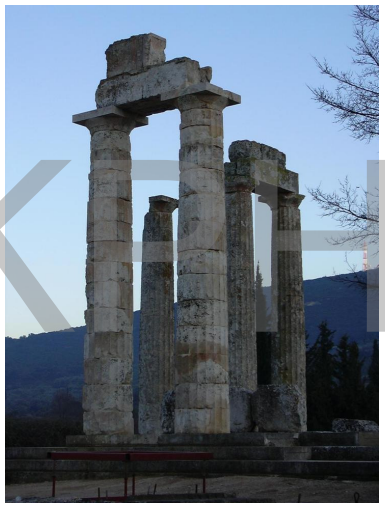


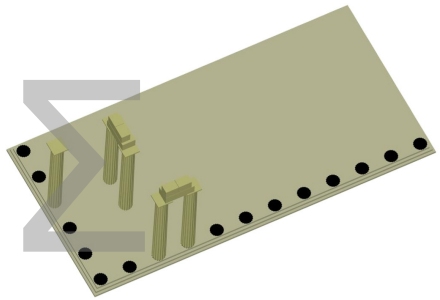
With the invaluable contribution of:

Dr. Kostas Zambas
Prof. Manolis Korres
Mr. Ioannis Arbilias



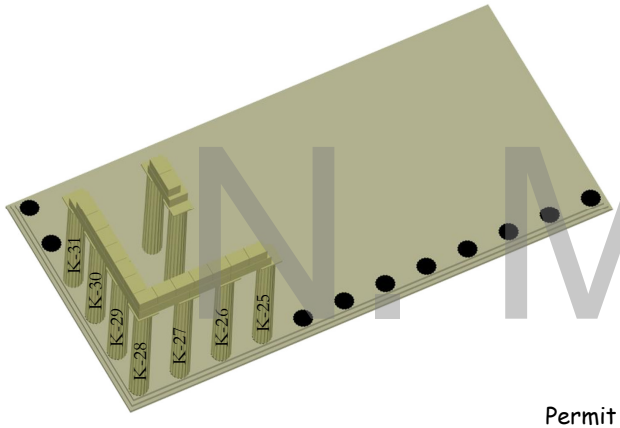
The pilot reconstruction: K-25 & K-26





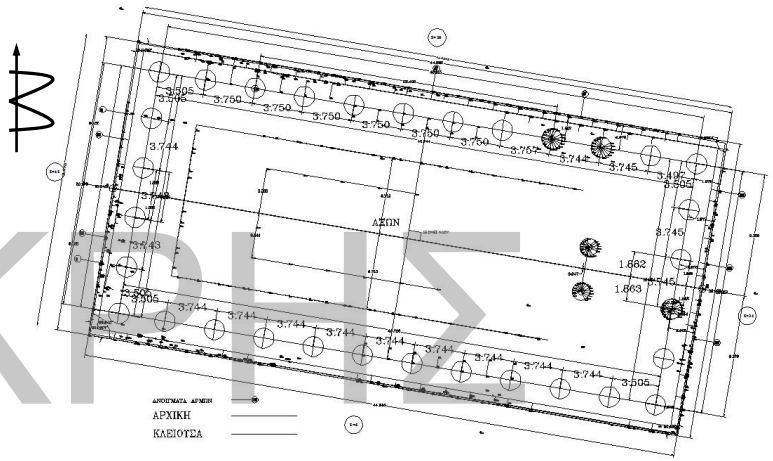
Completed: Summer 2002

The shape of the temple after the completion of the second phase. Reconstruction of K-27, K-28, K-29 & K-30

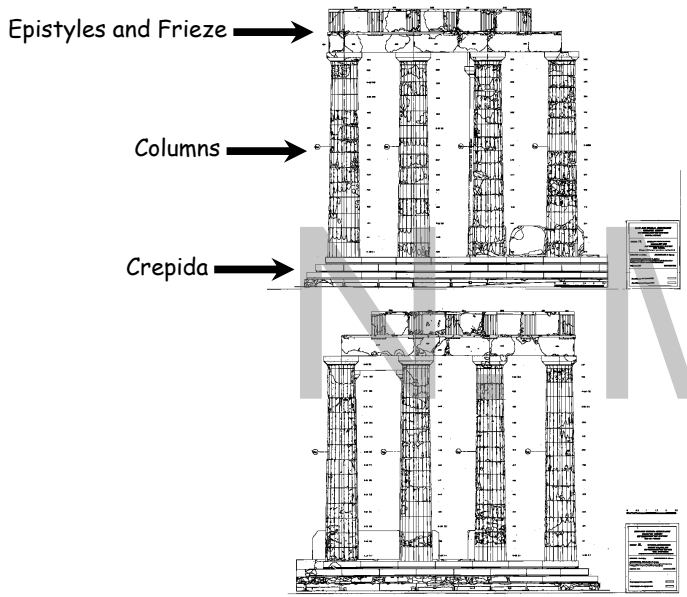


Permit issued on March 04 2004

Detailed surveying of the current situation of the monument



Establishment of the centers of the columns based on a sophisticated optimization analysis



Reconstruction of the crepida

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View of retrofitted ancient stones

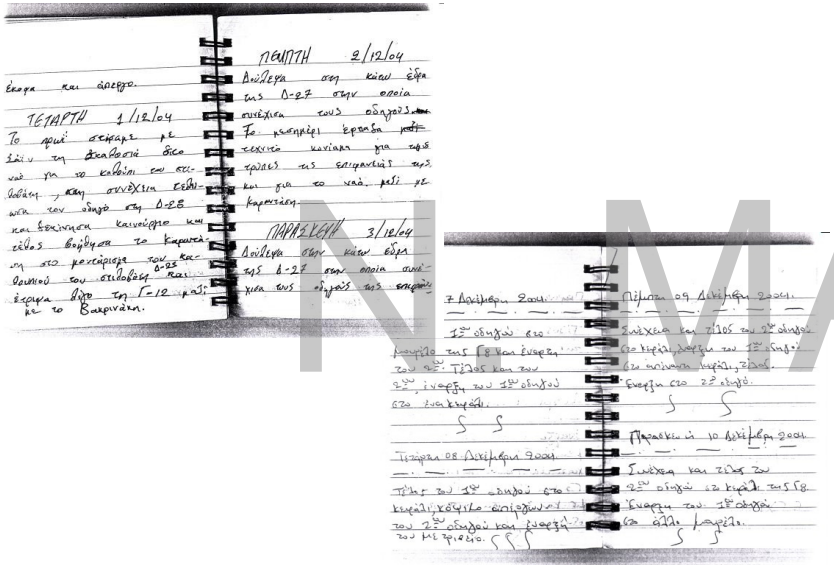
Wire-sawing and preparation of new material

Retrofit of Δ-25: stylobate of ancient column K-31


Δ=stylobate
Γ
Β
Α=euthenteria


Δ=stylobate
Γ
Β
Α=euthenteria
06.03.2007


06.03.2007



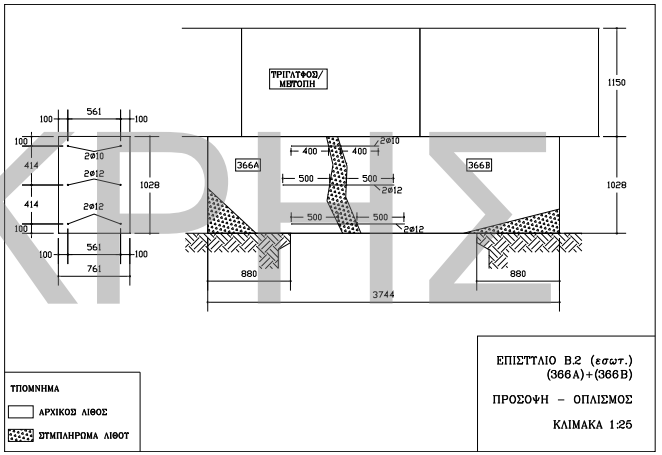
Need for retrofitting the column drums

View of final result of retrofitted drums

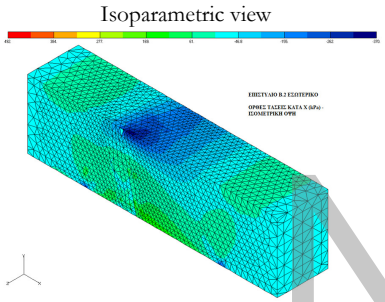
Works on existing and new column drums

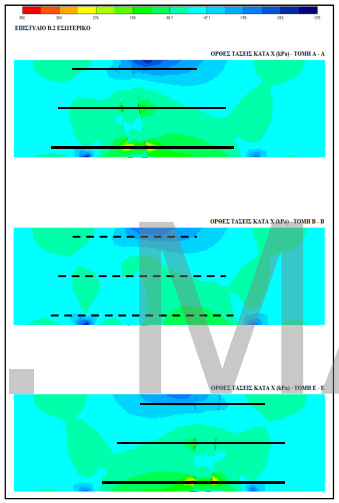
View of fragmented epistyles

Schematic of retrofitted epistyle



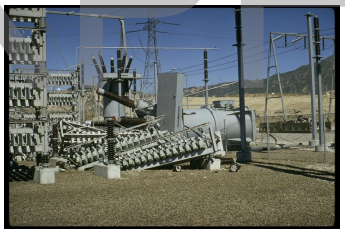
Normal stresses in the epistyle

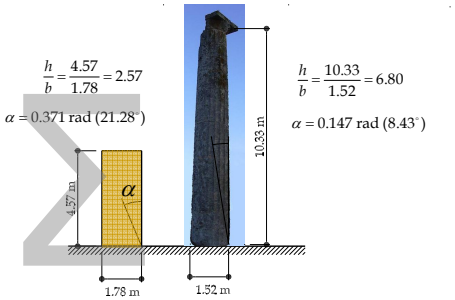




Les grands oeuvres de l' homme

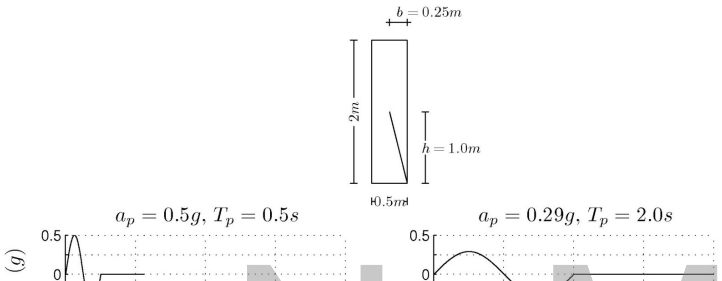
Seismic Stability of free-standing slender structures

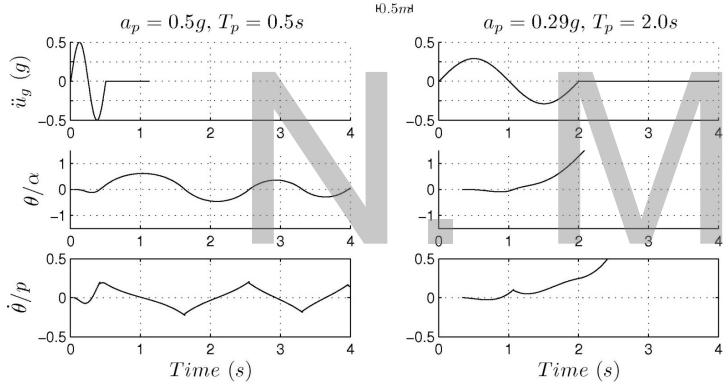




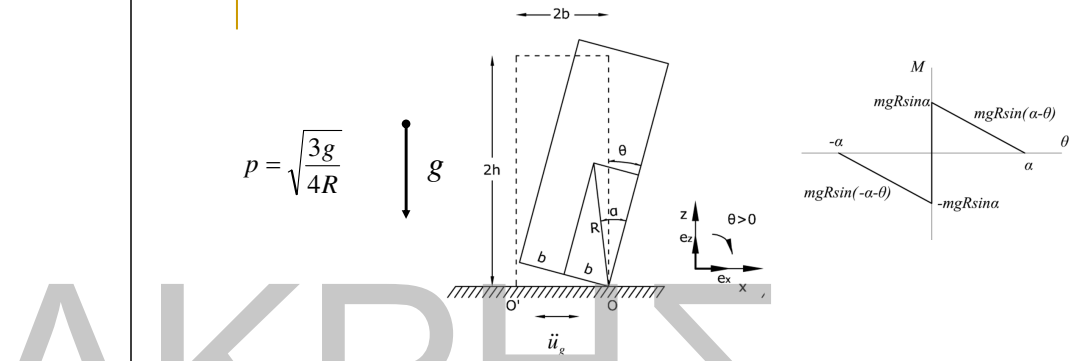
500 kV Electrical Transformer

Column K-31





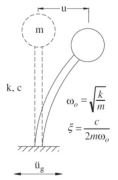
$$p = \sqrt{\frac{3g}{4R}}$$

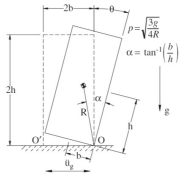


$$I_o\ddot{\theta}(t) + mgR\sin\left[-\alpha - \theta(t)\right] = -m\ddot{u}_g(t)R\cos\left[-\alpha - \theta(t)\right], \quad \theta(t) < 0$$

$$I_o\ddot{\theta}(t) + mgR\sin\left[\alpha - \theta(t)\right] = -m\ddot{u}_g(t)R\cos\left[\alpha - \theta(t)\right], \quad \theta(t) > 0$$

$$\ddot{\theta}(t) = -p^2\left\{\sin\left[\alpha\,\mathrm{sgn}\left(\theta(t)\right) - \theta(t)\right] + \frac{\ddot{u}_g}{g}\cos\left[\alpha\,\mathrm{sgn}\left(\theta(t)\right) - \theta(t)\right]\right.$$



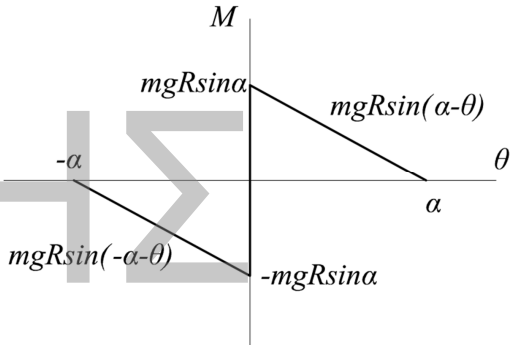


Parameters/ characteristics	Damped oscillator m, c, k	Rocking rigid block b, h, g
Restoring mechanism	Elasticity of the structure	Gravity
Restoring force/moment	$F = ku$ (*for linear springs*)	$M = mgR\sin(\alpha - \theta)$ $R = \sqrt{b^2 + h^2}$
Stiffness at stable equilibrium	Finite	Infinite
Restoring force/moment at stable equilibrium	Zero	Finite: $mgR\sin(\alpha)$
Stiffness away from equilibrium	Positive	Negative
Frequency parameter	Undamped natural frequency: $\omega_0 = \frac{2\pi}{T_o} = \sqrt{\frac{k}{m}}$	Frequency parameter: $p = \sqrt{\frac{3g}{4R}}$ (*for rectangular blocks*)
Damping parameter	Viscous damping ratio: $\xi = \frac{c}{2m\omega_0}$	Slenderness: $\alpha = \tan^{-1}(b/h)$

$$I_o\dot{\theta}_1 - m\dot{\theta}_1 2bR\sin(\alpha) = I_o\dot{\theta}_2$$

$$r = \frac{\dot{\theta}_2^2}{\dot{\theta}_1^2}$$

$$r = [1 - \frac{3}{2}\sin^2\alpha]^2$$



Dimensionless Products

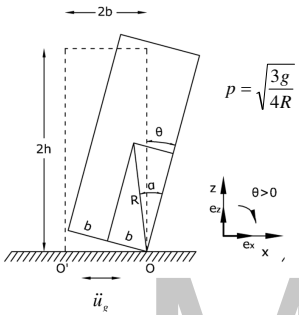
$$\Pi_\theta = \theta$$

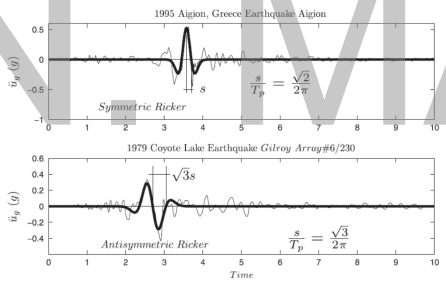
$$\Pi_\omega = \frac{\omega_p}{p}$$

$$\Pi_\alpha = \tan(\alpha)$$

$$\Pi_g = \frac{a_p}{g}$$

$$\theta(t) = \varphi(\frac{\omega_p}{p}, \tan\alpha, \frac{a_p}{g})$$

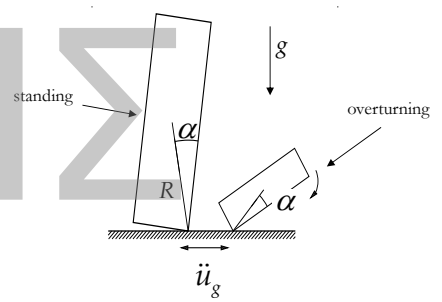




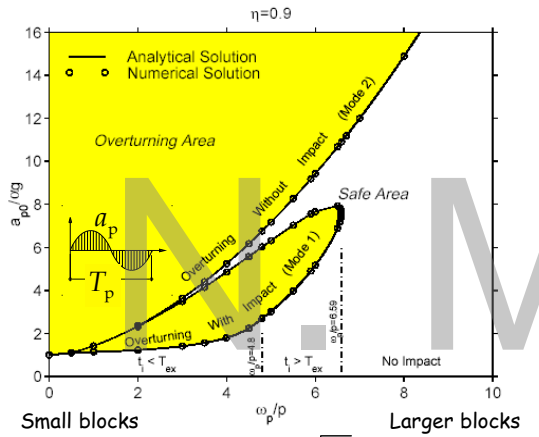
Fundamental size-frequency effect: 1963 George W. Housner

(a) The larger of two geometrically similar blocks can survive the excitation that will topple the smaller block; and (b) out of two same acceleration-amplitude pulses the one with the longer duration is more capable to induce overturning

Conclusion reached from studies motivated from the destruction observed after the May 1960 earthquake in Chile.



Zhang & Makris 2002

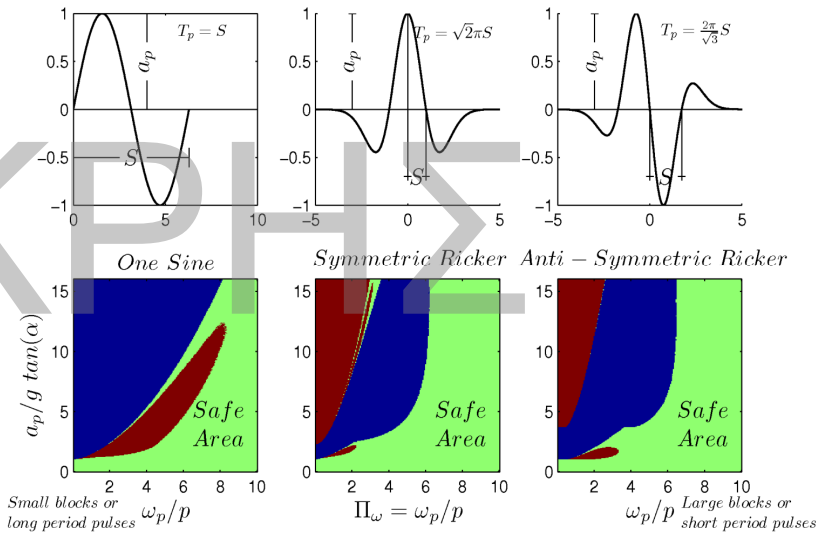


Small blocks or long period pulses

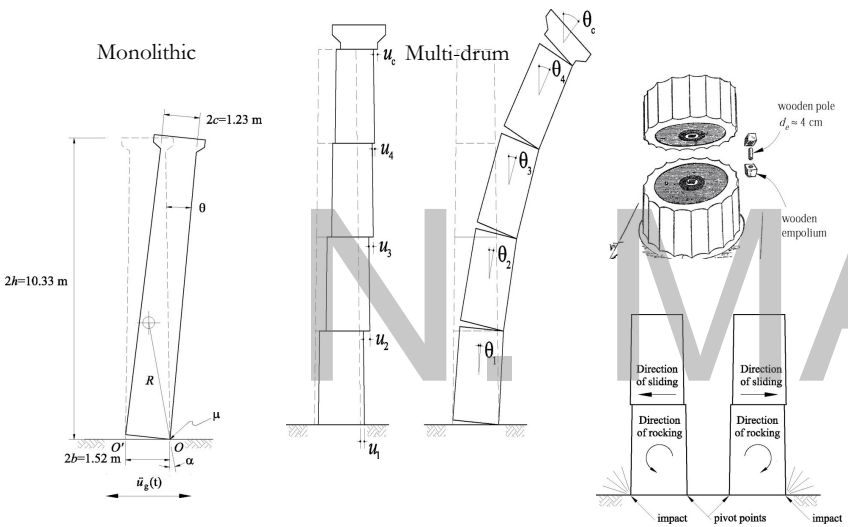
$$\omega_p = \frac{2\pi}{T_p}, \quad p = \sqrt{\frac{3g}{4R}}$$

Larger blocks or high frequency pulses

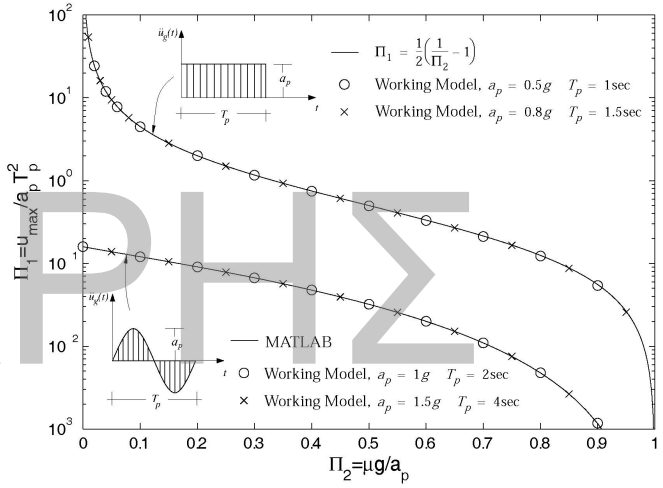
Overturning spectra of a rigid block standing free on a monolithic base

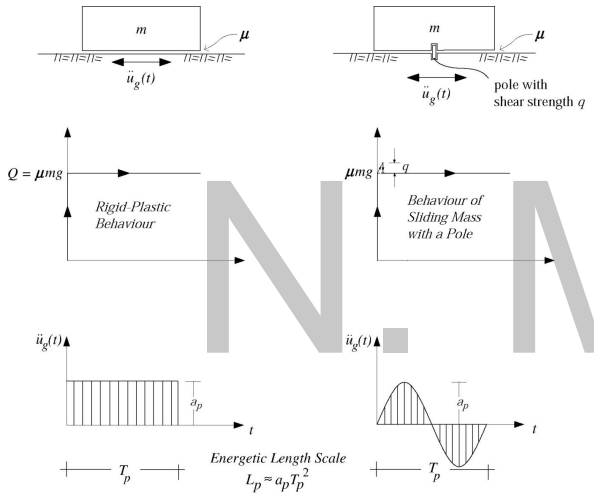


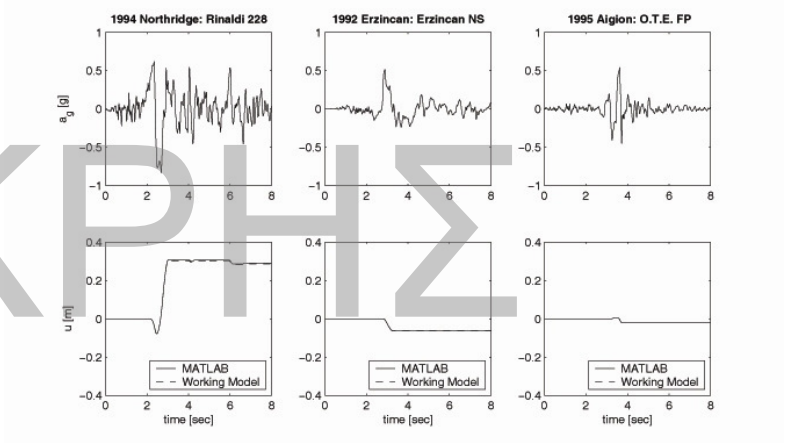
Seismic response of monolithic and multi-drum column

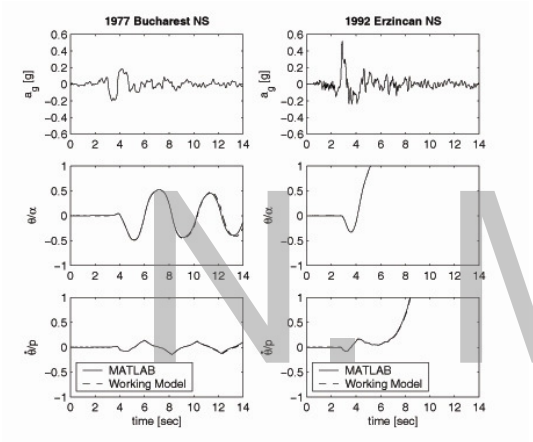


Peak Displacement of a Sliding Block Subjected to Square and One-Sine Pulse Excitations

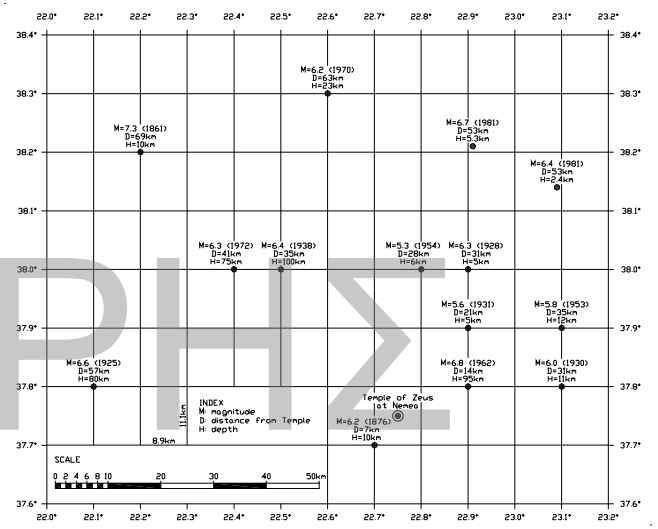








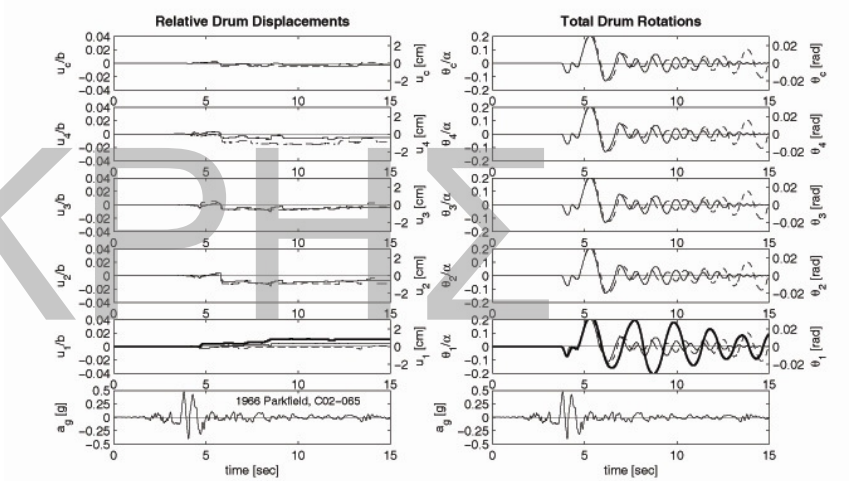
Seismic Hazard

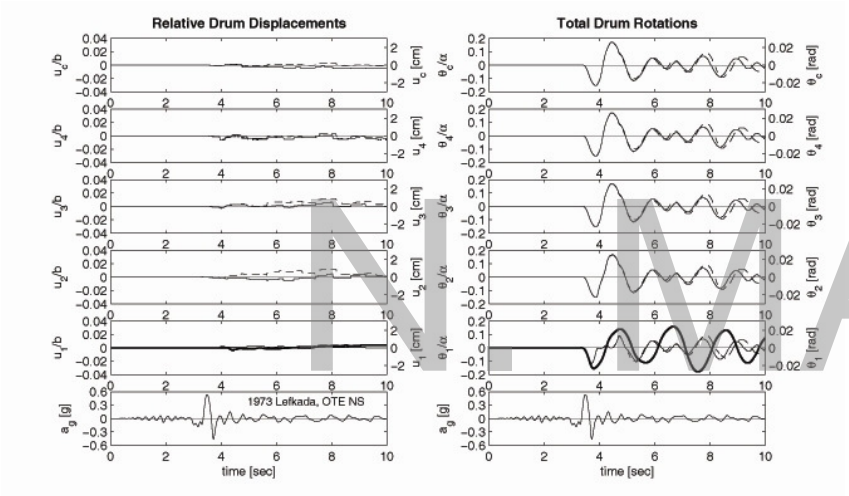


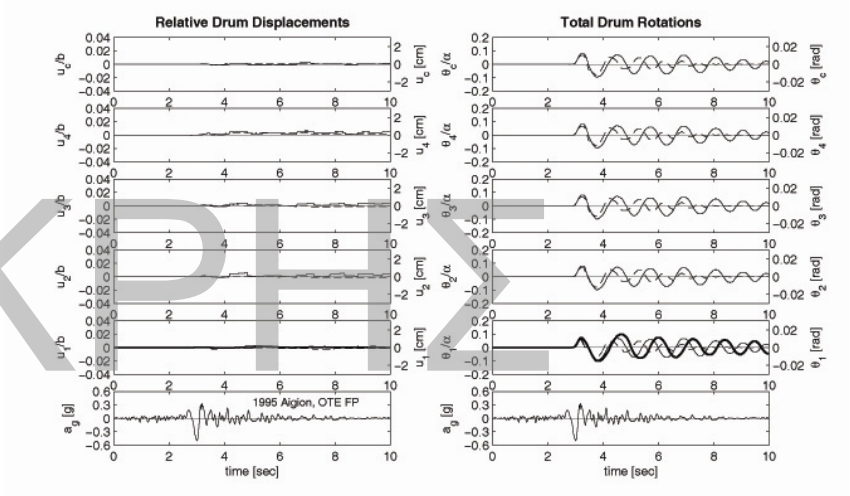
Location of selected historic earthquakes nearby the Temple of Zeus at Nemea.

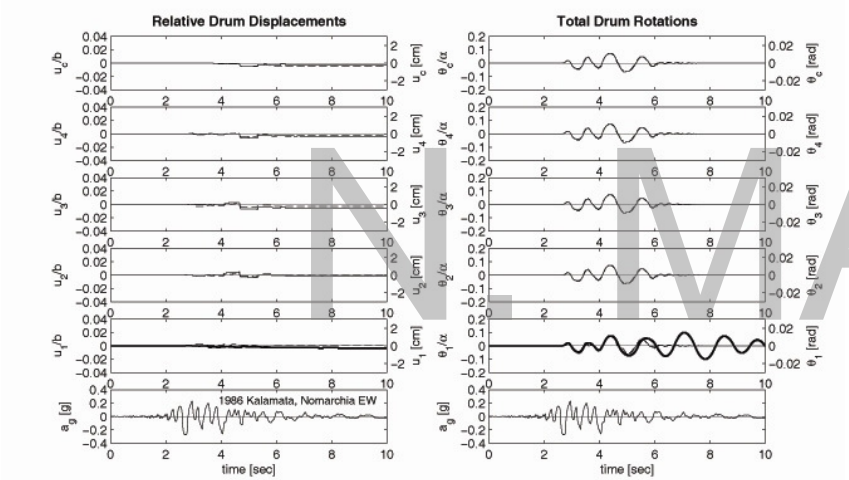
Table. Seismic Records that Represent to the Extent Possible the Seismic Hazard of the Area of the Temple of Zeus.

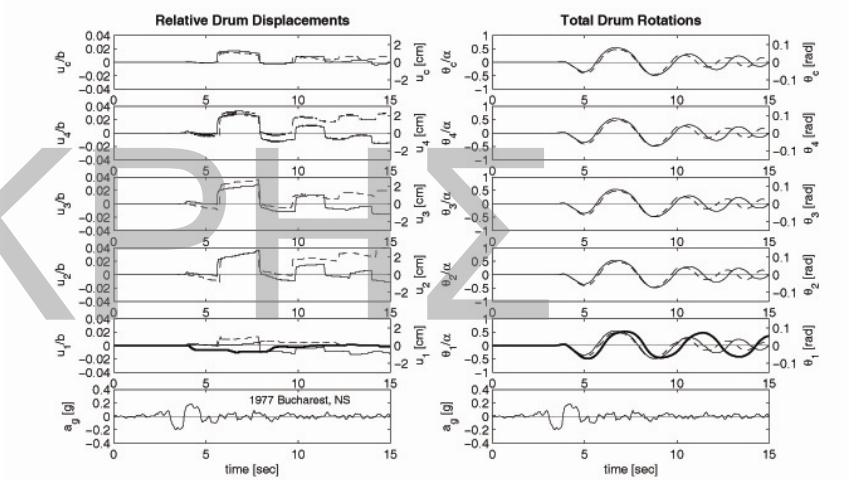
EARTHQUAKE	DATE	MAGN. M	RECORDING STATION	LOCAL SITE CONDITIONS	DIST. D (km)	PGA g	PGV cm/sec	PGD cm
Superstition Hills	1987 Nov. 24	6.7	El Centro Imperial Country	soil	13.9	0.36	46.4	16.0
			Westmoreland Fire Station	soil	13.3	0.21	31.0	20.1
Northridge	1994 Jan. 17	6.7	Simi Valley, Katherine Rd	soil	14.6	0.88	40.8	5.3
			Sun Valley, Roskoe Blvd	soil	12.3	0.44	38.3	10.0
Parkfield	1966 June 28	6.1	Temblor	rock	9.9	0.36	21.4	3.5
Leukada	1973 Nov. 04	6.0	OTE building	soil	20	0.53	55.0	11.6
Aigion	1995 June 15	6.2	OTE building	soft rock	18	0.50	43.3	7.1
Kalamata	1986 Sept. 13	6.0	Nomarhia building	hard soil	5.0	0.27	24.2	5.6
Parnitha	1999 Sept. 07	5.9	Sepolia B	13 m deposits of limestone	8.0	0.32	21.5	2.7
Bucharest	1977 March 04	7.2	Bucharest	soil	160	0.20	73.4	20.4
Kocaeli	1999 Aug. 17	7.4	Sakarya	soil	3.1	0.38	79.4	71.4

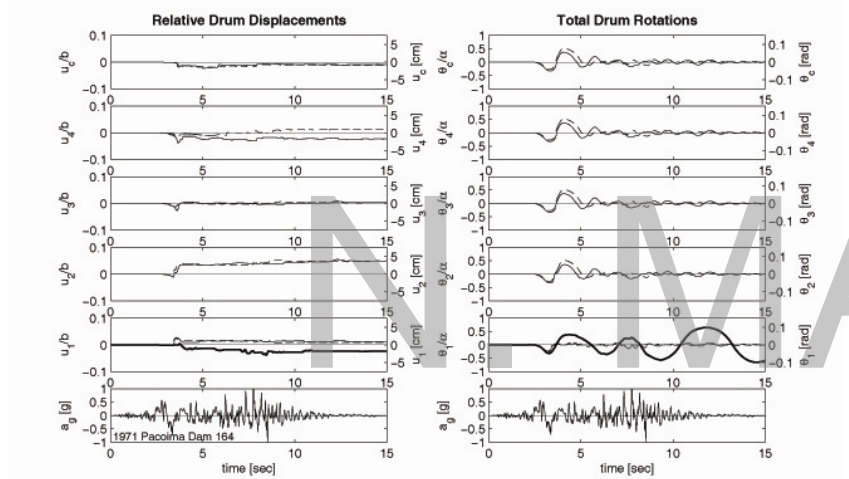


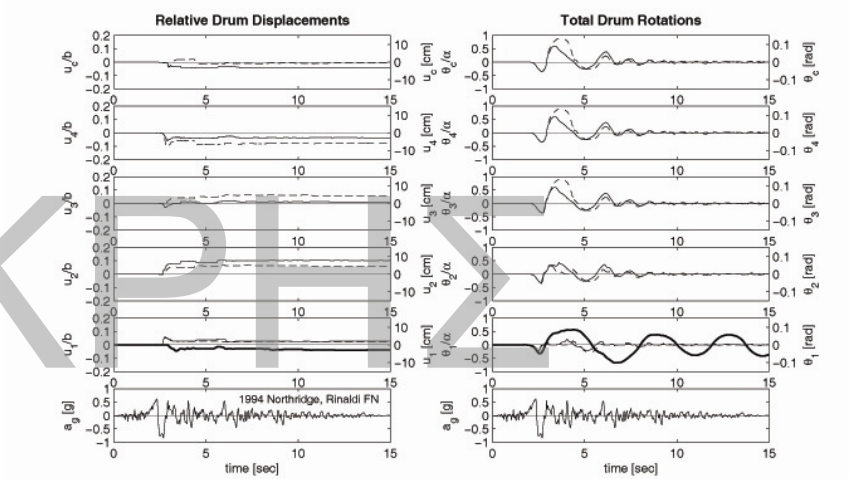


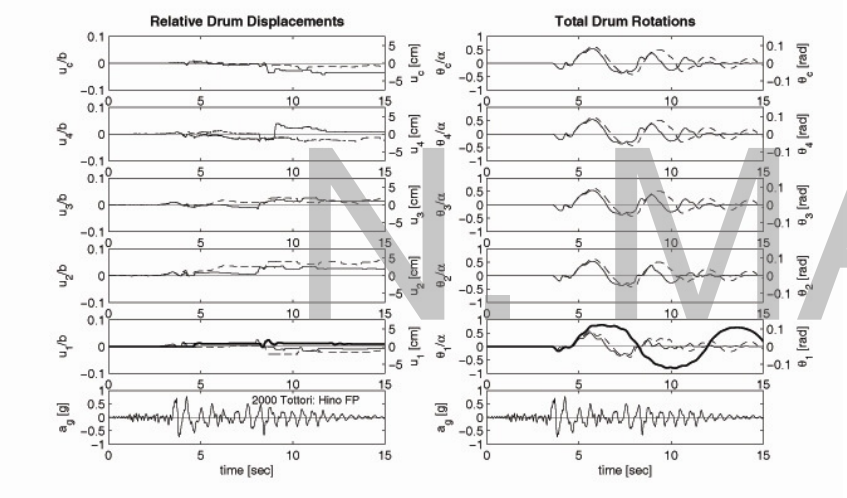


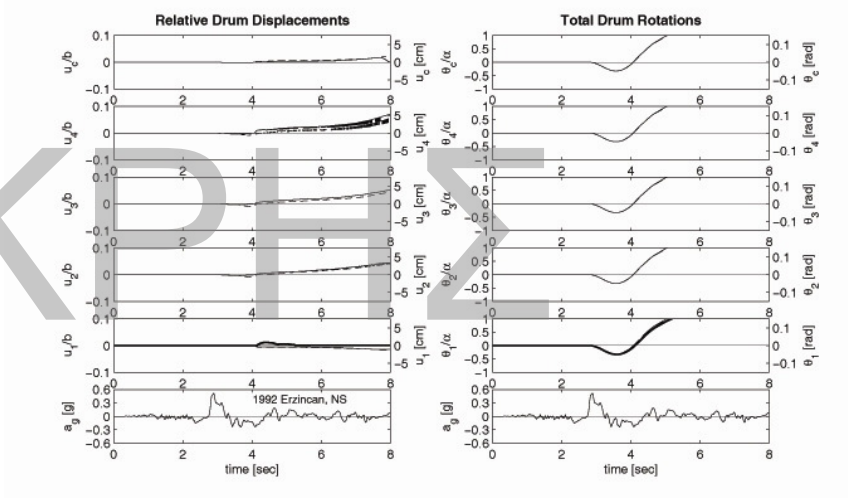

Relative Drum Displacements
Total Drum Rotations
1986 Kalamata, Nomarchia EW
time [sec]

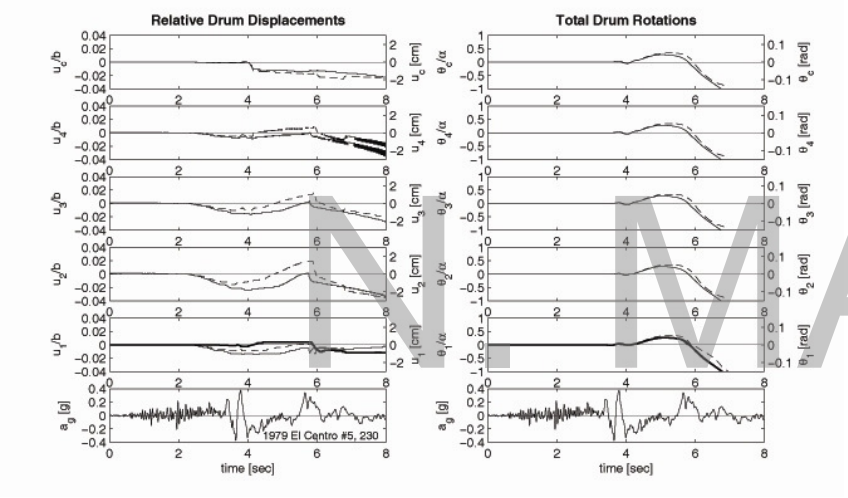

Relative Drum Displacements
Total Drum Rotations
1977 Bucharest, NS
time [sec]

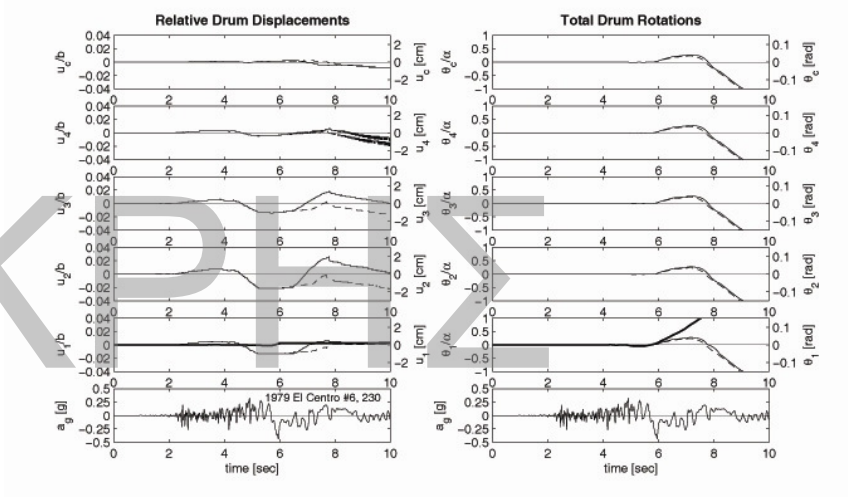

Relative Drum Displacements
Total Drum Rotations
1971 Pacoima Dam 164
time [sec]

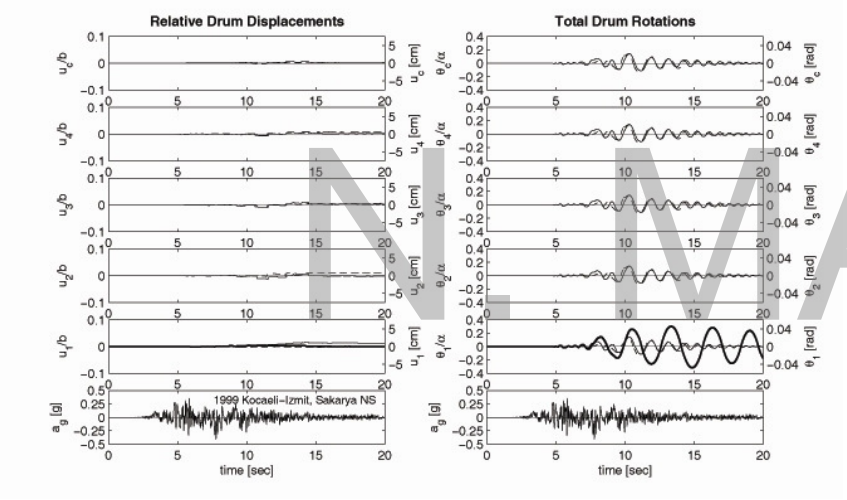

Relative Drum Displacements
Total Drum Rotations
1994 Northridge, Rinaldi FN
time [sec]


Relative Drum Displacements
Total Drum Rotations
2000 Tottori: Hino FP
time [sec]


Relative Drum Displacements
Total Drum Rotations
1992 Erzincan, NS
time [sec]


Relative Drum Displacements
Total Drum Rotations
1979 El Centro #5, 230
time [sec]


Relative Drum Displacements
Total Drum Rotations
1979 El Centro #6, 230
time [sec]



Peak column rotations from various historic strong earthquake motions