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پرتال جامع دانشجویان و مهندسين عمران

ارائه كتابها و جزوات رايجان مهندسي عمران

بهترين و برترين مقالات روز عمران

انجمن هاي تفصلي مهندسي عمران

خوشگاه تفصلي مهندسي عمران

میراگر مایع هماهنگ شده

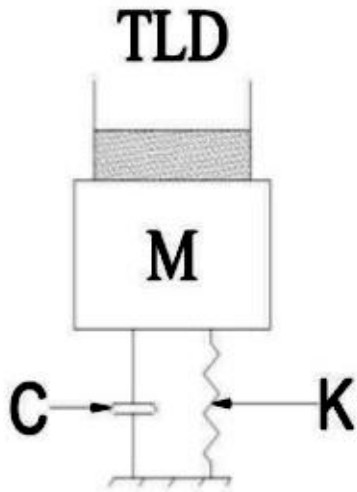
TUNED LIQUID DAMPER (TLD)

ارائه:

م.امری

پاییز ۱۳۹۳

معرفی میراگرهای قابل تنظیم مایع (TLD)



- مشابه میراگر قابل تنظیم وزنی می باشد.
- نیاز به مقدار زیادی مایع برای کار دارند.
- مایع مورد استفاده معمولاً آب می باشد.
- زمانی موثر می باشند که فرکانس تحریک نزدیک به فرکانس طبیعی سیستم باشد.
- حرکت موجی آب موجب استهلاک انرژی می گردد.
- معمولاً برای کاهش اثرات تحریک ناشی از باد مورد استفاده قرار می گیرد.

مزایا:

- هزینه نصب پایین.
- عدم وجود قسمت متحرک.
- هزینه استفاده و نگهداری پایین.
- کنترل فرکانس با تنظیم ارتفاع مایع.
- مقاوم در برابر باد و زلزله
- استفاده آنی

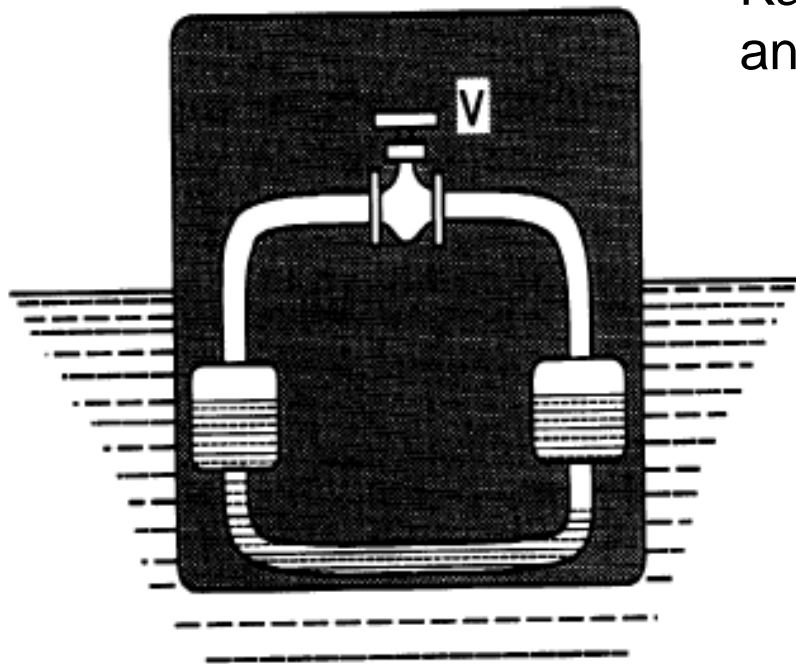
تاریخچه

TLD در اواخر ۱۸۰۰ برای کاهش نوسانات کشتی های معرفی گردید.

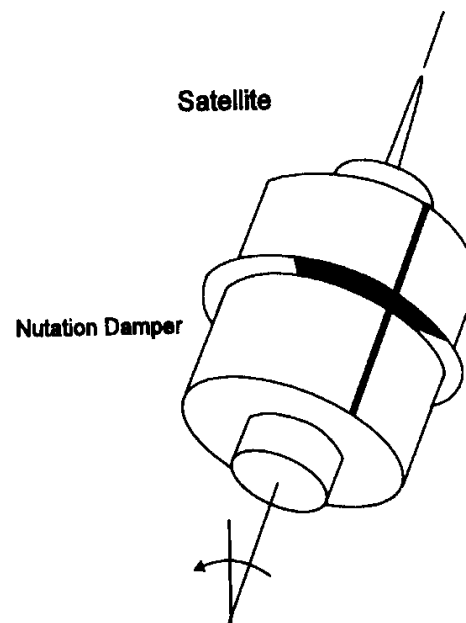
Den Hartog, 1956

کاربرد سازه‌ای:

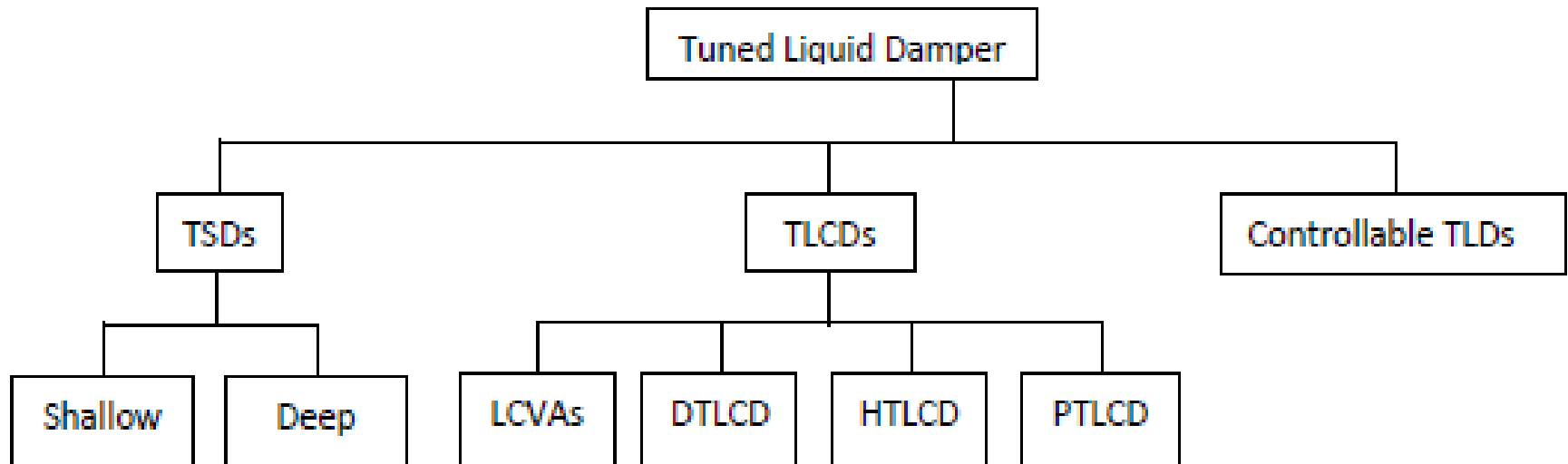
Kareem and Sun(1987); Modi et al. (1987)
and Fujino et al. (1988)



Frahm Anti-rolling tanks

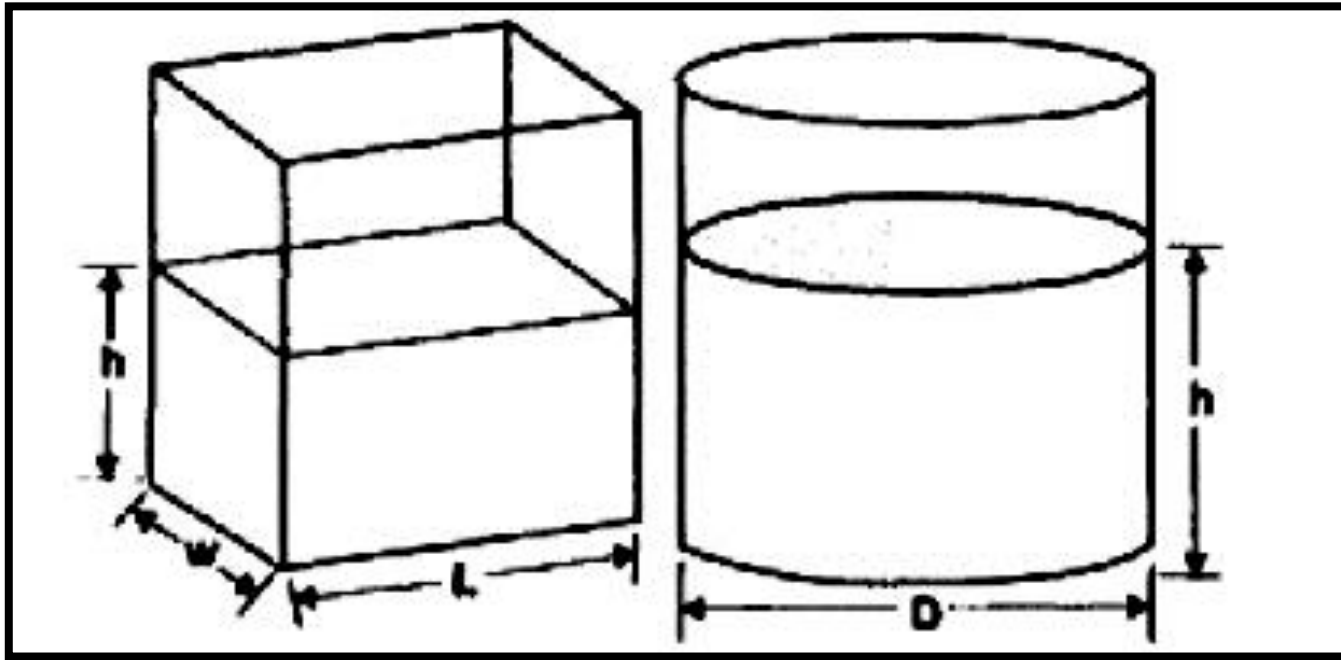


TLD خانواده



TSD: Tuned Sloshing Damper, TLCD: Tuned Liquid Column Damper, LCVA: Liquid Column Vibration Absorbers, DTLCD: Double Tuned Liquid Column Damper, HTLCD: Hybrid Tuned Liquid Column Damper, PTLCD: Pressurized Tuned Liquid Column Damper, ER: Electro Rheological, & MR: Magneto Rheological.

Tuned Sloshing Damper (TSD)

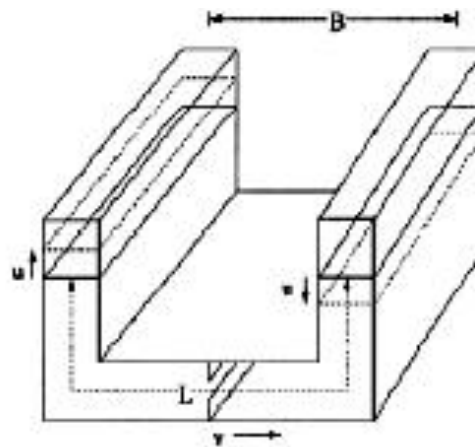
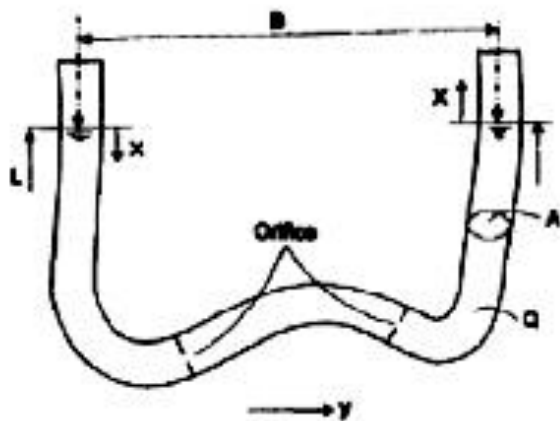


$$\frac{h}{L \text{ or } D} < 0.15 \rightarrow \textit{shallow}$$

$$\frac{h}{L \text{ or } D} > 0.15 \rightarrow \textit{deep}$$

Tuned Liquid Column Damper(TLCD)

Sakai *et al.* (1991)



- شکل دلخواه
- قابلیت نصب راحت در سازه‌های موجود
- مکانیزم قابل فهم تر
- کنترل ظرفیت میرایی
- کنترل فرکانس میراگر با تنظیم ارتفاع آب

Liquid Column Vibration Absorber (LCVA)

(Hitchcock *et al.* 1997; Chang and Hsu, 1998)

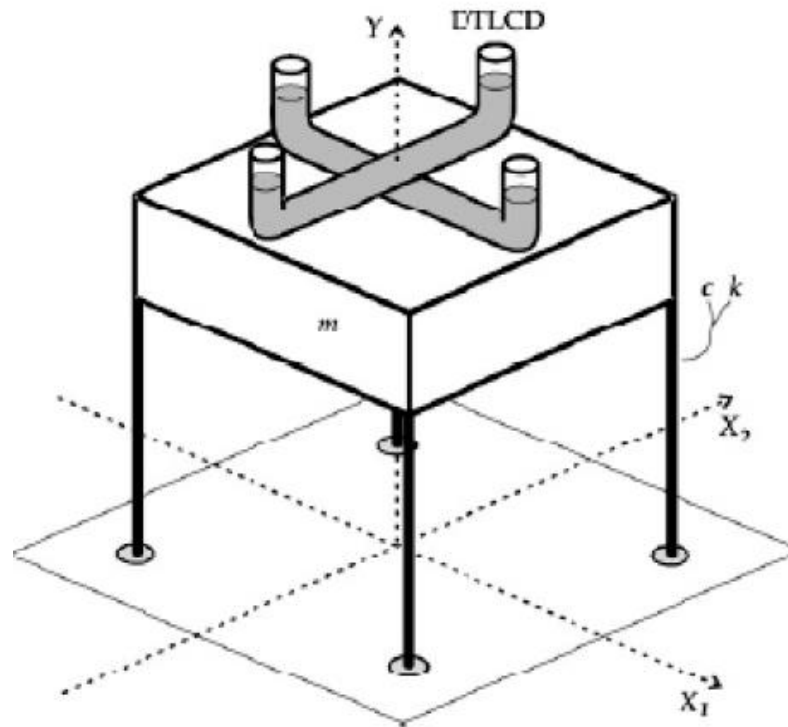
در مقایسه با TLCD

- دارای مقاطع متغییر در ارتفاع و طول می باشد.
- امکان تنظیم فرکانس در محدوده وسیع را دارا می باشد.
- فرکانس طبیعی نه تنها با ارتفاع آب بلکه با نسبت طول به سطح مقطع افقی و عمودی نیز قابل تنظیم است.

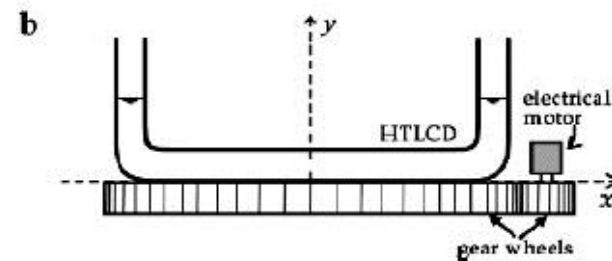
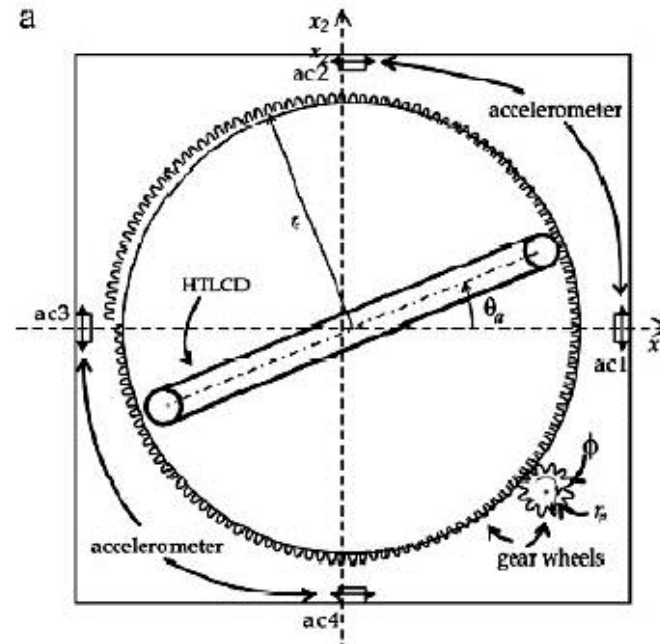
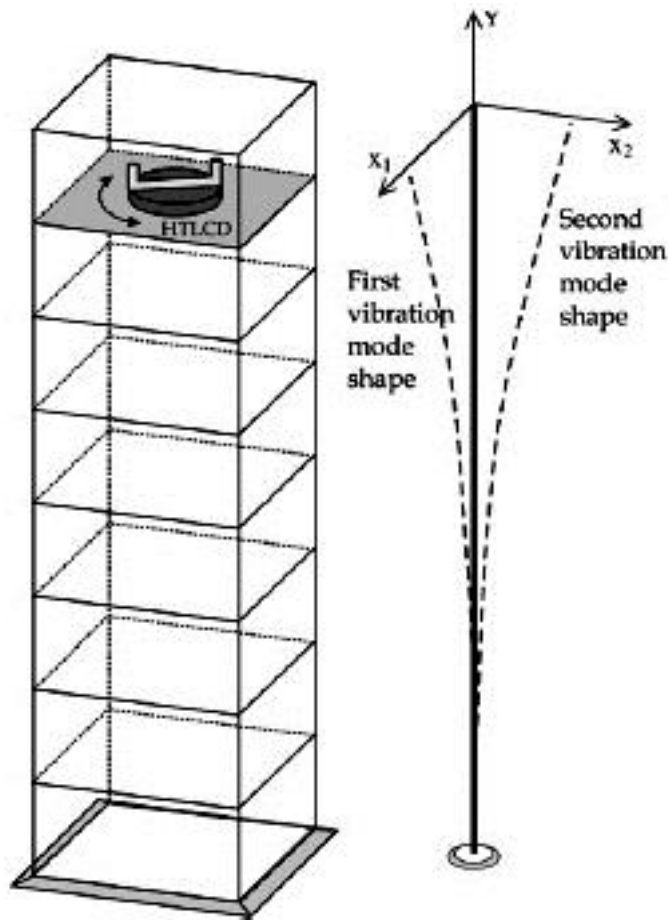
Double Tuned Liquid Column Damper (DTLCD)

(Kareem, 1993)

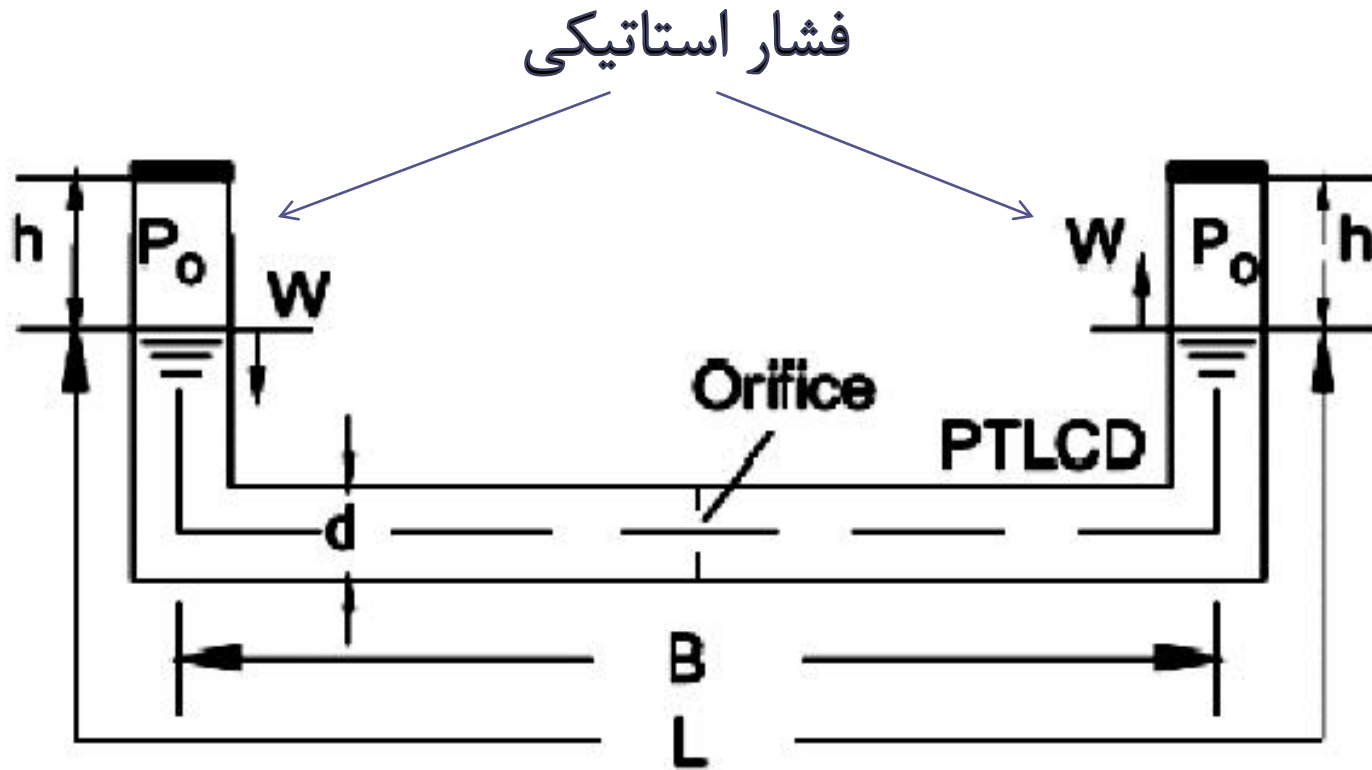
سازه معمولا تحت هر دو تحریک جانبی و پیچشی می باشد.



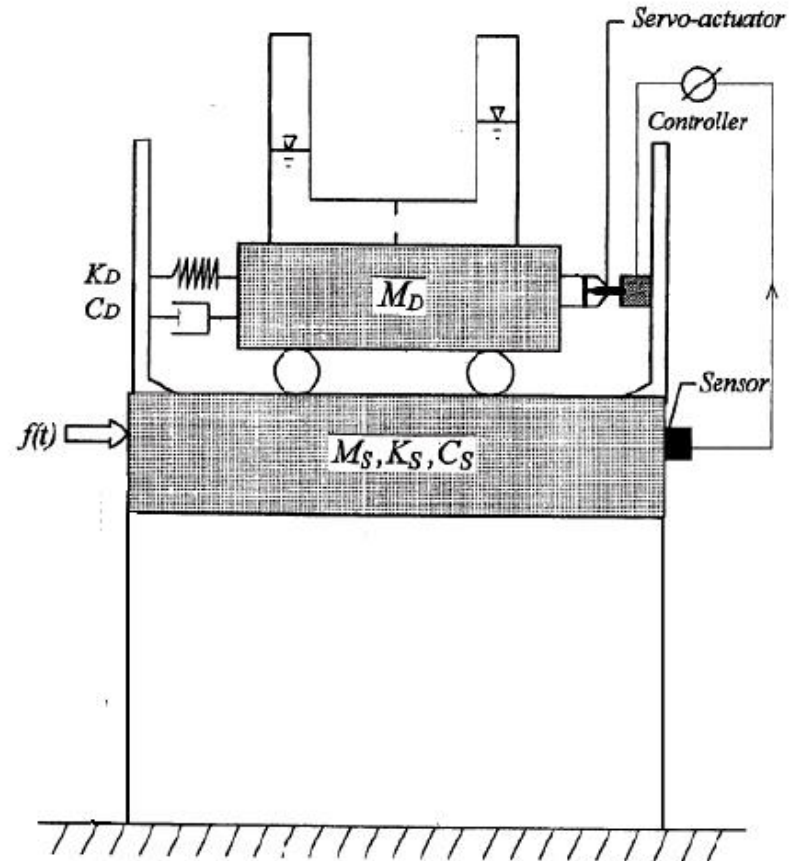
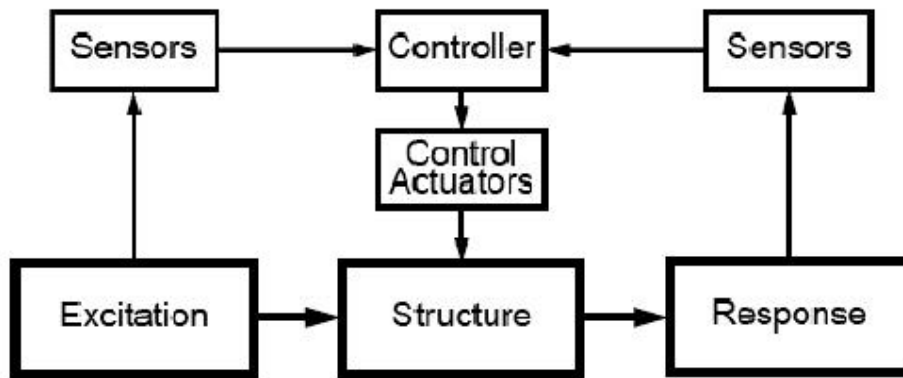
Hybrid Tuned Liquid Column Damper (HTLCDD)



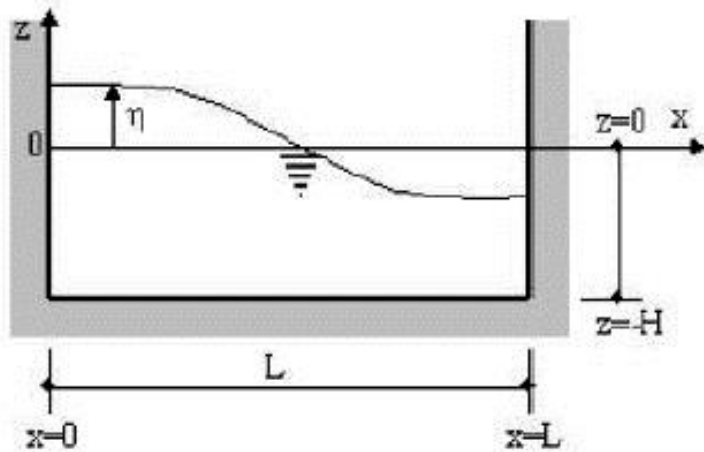
Pressurized tuned liquid Column Damper (PTLCD)



Controllable Tuned Liquid Damper



تئوری میراگرهای مایع



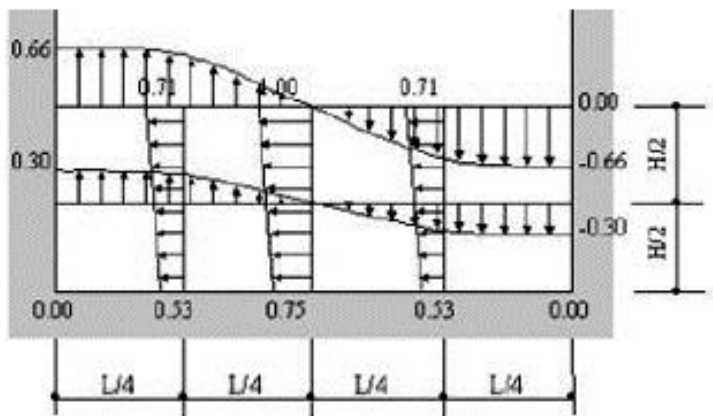
$$\eta = \frac{1}{g} \left(\frac{\partial \phi}{\partial t} \right)_{z=H} = \frac{2C_1 \omega}{g} \cos \frac{\pi x}{L} \sin \omega t$$

$$\dot{x} = \frac{\partial \phi}{\partial x} = -\frac{2C_1 \pi}{L} \frac{\cosh[\pi(z+H)/L]}{\cosh(\pi H/L)} \sin \frac{\pi x}{L} \cos \omega t$$

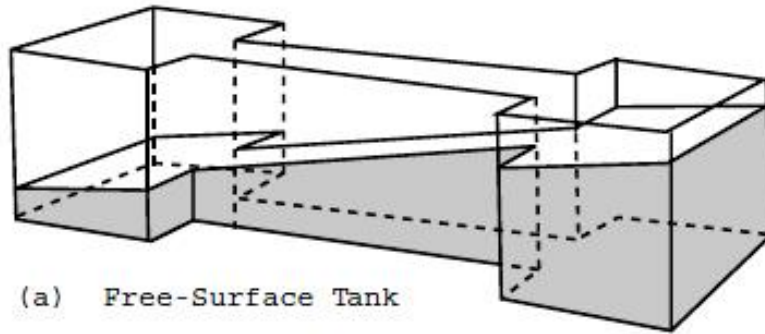
$$\dot{z} = \frac{\partial \phi}{\partial z} = \frac{2C_1 \pi}{L} \frac{\sinh[\pi(z+H)/L]}{\cosh(\pi H/L)} \cos \frac{\pi x}{L} \cos \omega t$$

$$\xi_{eq} = \alpha \sqrt{\left(\frac{D}{L} \right)^\beta}, \quad f_n = \frac{1}{2\pi} \sqrt{\frac{\pi g}{L} \tanh\left(\frac{\pi H}{L}\right)}, \quad \gamma = \frac{f}{F_n}$$

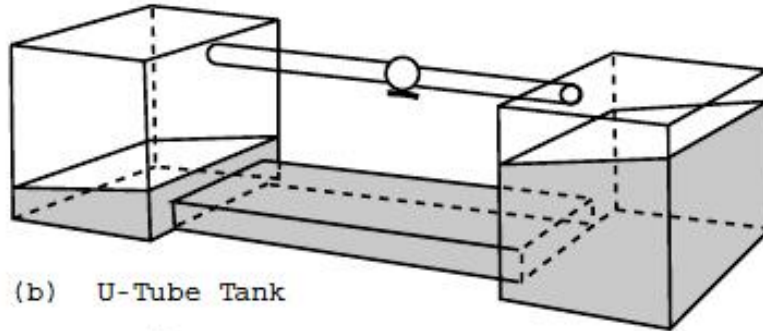
$$D.A.F = \frac{\gamma^2}{\sqrt{(1-\gamma^2)^2 + 4\xi^2 \gamma^2}}$$



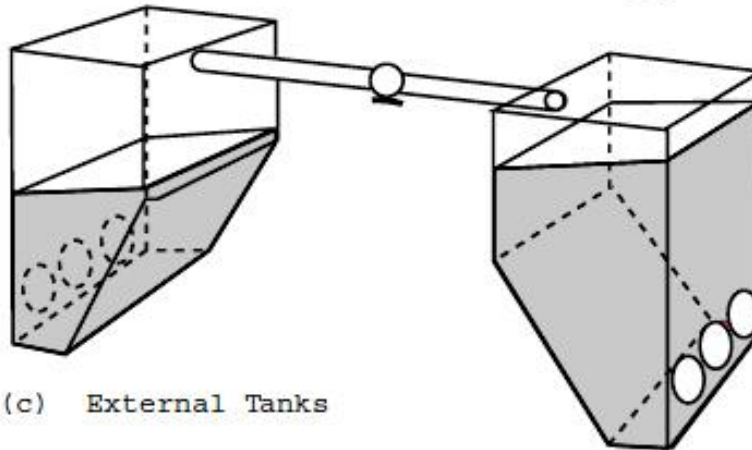
کاربرد میراگرهای مایع در کشتی ها



(a) Free-Surface Tank



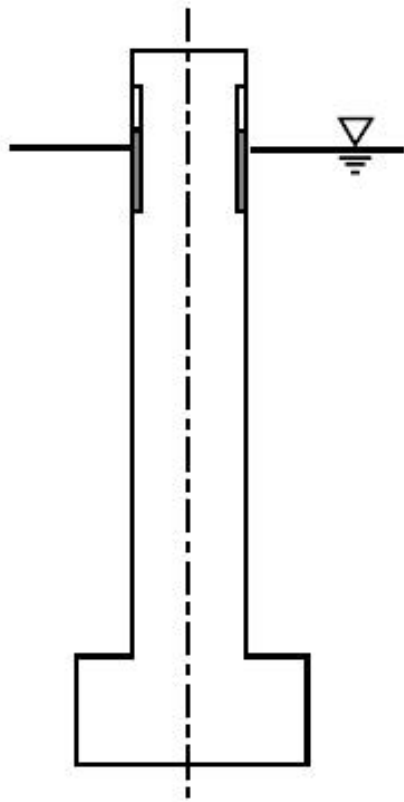
(b) U-Tube Tank



(c) External Tanks

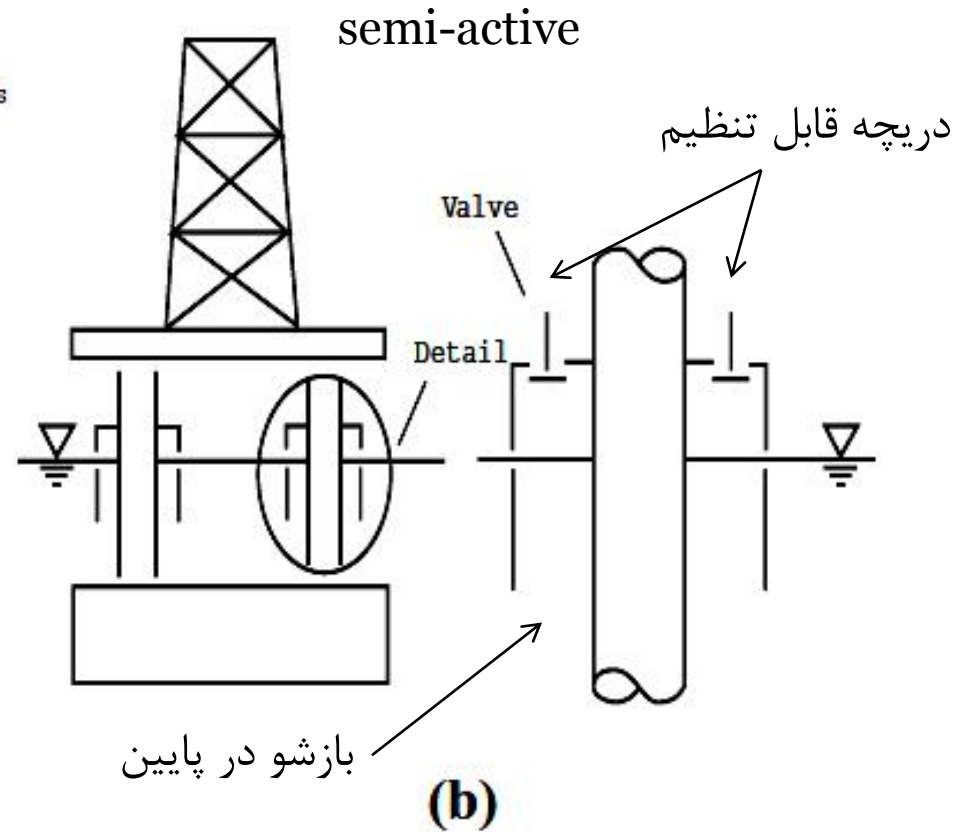
کاربرد میراگرهای مایع در Offshore

Huse (1987)



(a)

Ehlers (1987)



(b)

کاربردهای سازه‌ای

Gold Tower in Chiba, Japan



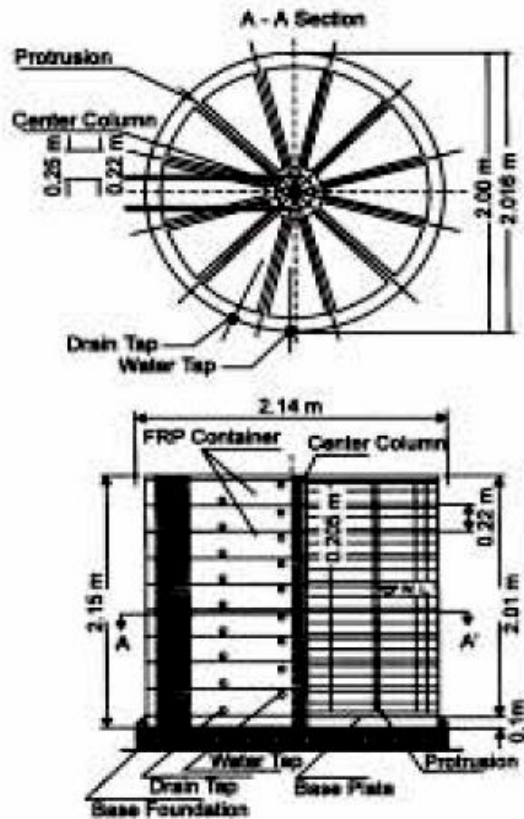
Aqua Damper

- تعداد ۱۶ عدد
- وزن آب ۱۰ تن
- بهبود ۵۰ الی ۶۰ درصدی پاسخ سازه
- در طبقه فوقانی برج در ارتفاع ۱۵۸ متری

کاربردهای سازه‌ای

Shin Yokohama Prince Hotel (SYPH)

Tamura *et al.* 1995



(a)



(b)

-تعداد ۹ کانتینر استوانه‌ای

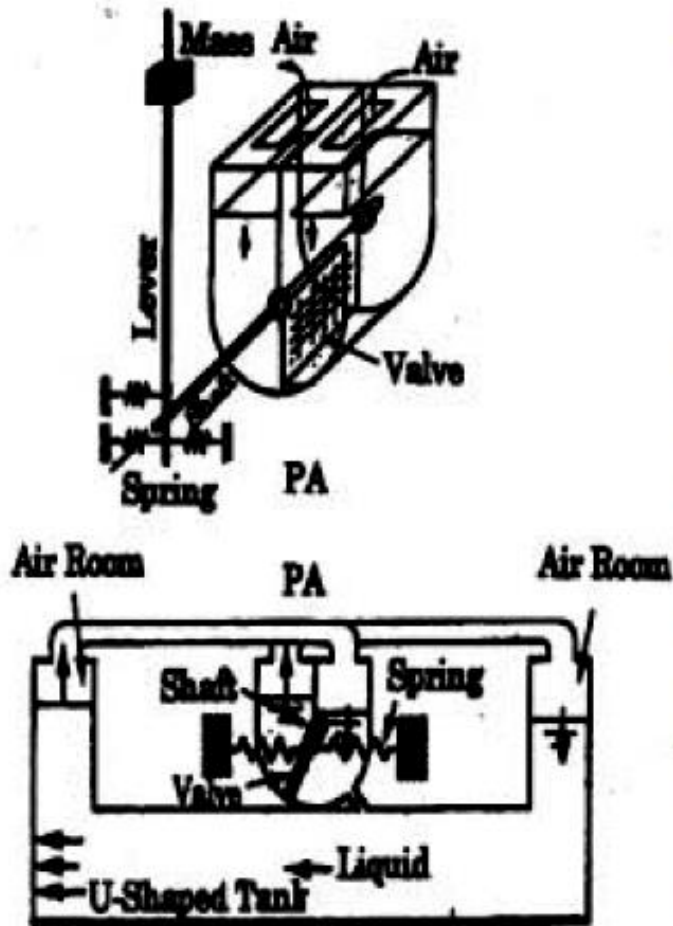
-کاهش ۵۰ الی ۷۰ درصدی

شتاب طبقه فوقانی ناشی از باد

Hotel Cosima in Tokyo

Shimizu and Teramura, 1994

کاربردهای سازه‌ای



(a)



(b)

۲۶- طبقه

فلزی

- ارتفاع ۱۰۶.۲ متر

- وزن آن ۵۸ تن

- فشار قابل تنظیم

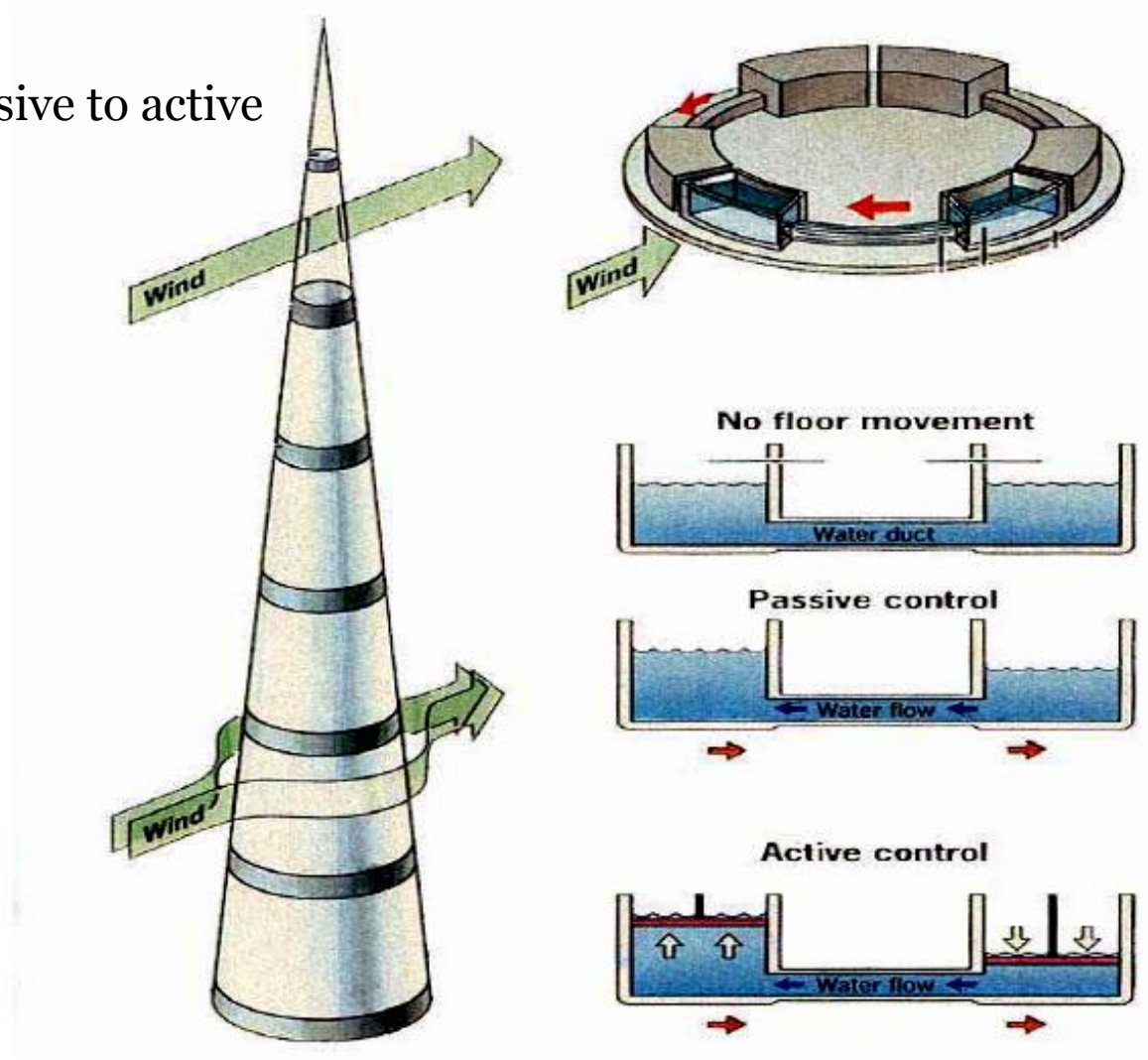
- ۵۰ الی ۷۰ درصدی

کاربردهای سازه‌ای

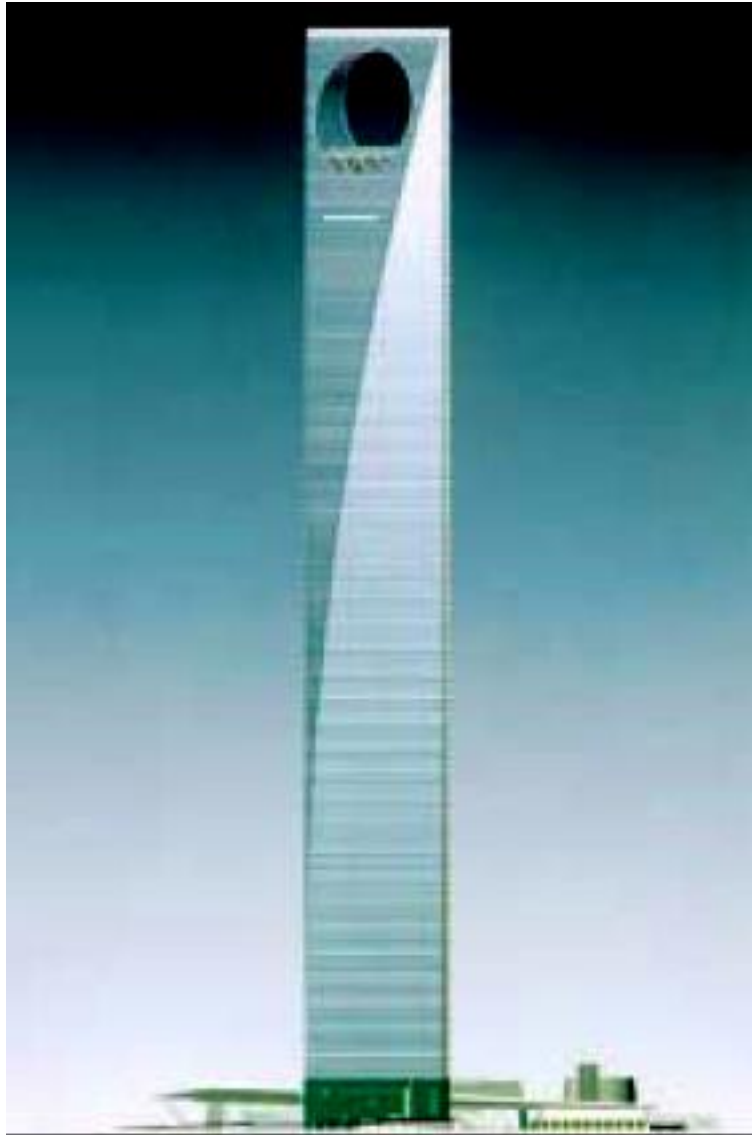
Millennium Tower, Tokyo Bay, Japan

Sudjic, 1993

control mode from passive to active



Shangai Financial Trade Center in China



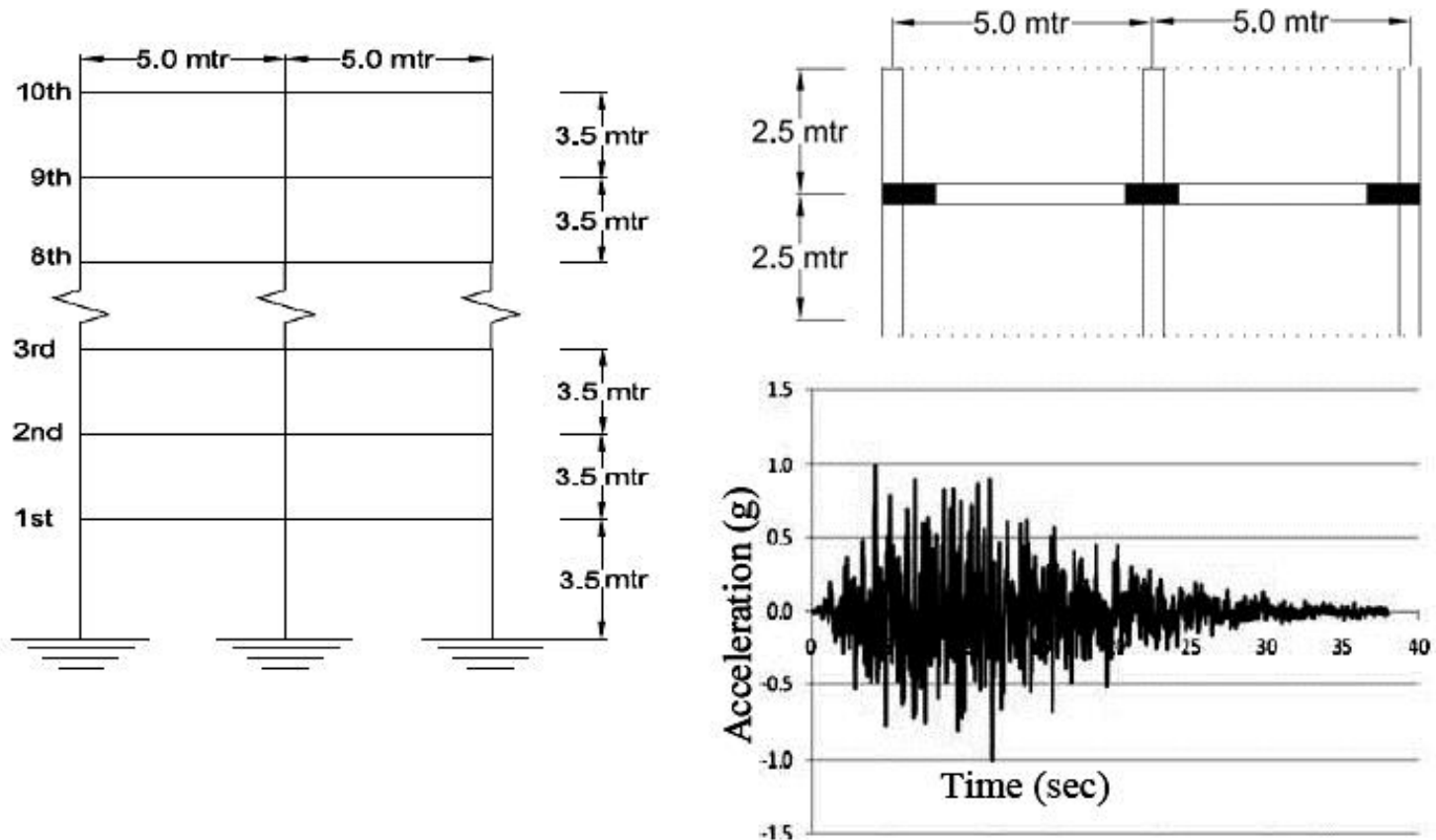
کاربردهای سازه‌ای

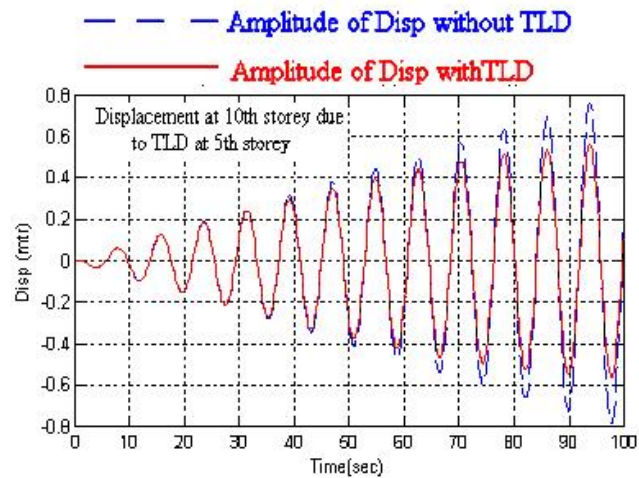
South Dearborn project



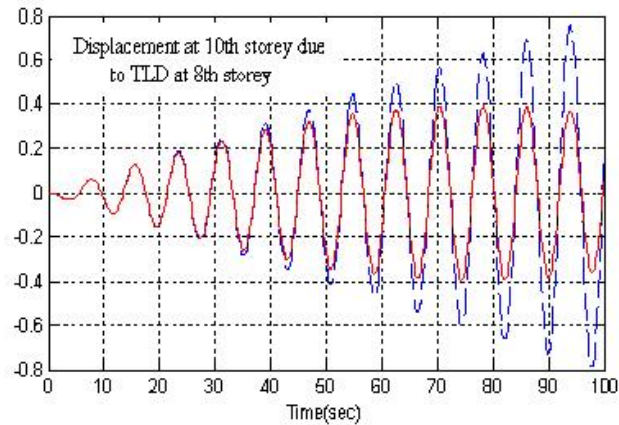
بررسی کارایی TLD در زمین لرزه‌ها

BHARADWAJ NANDA AND KISHORE CHANDRA BISWAL(2011)

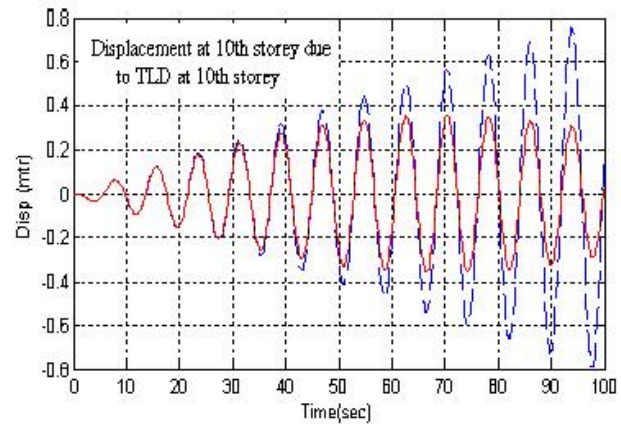




(a) Displacement of 10th storey due to TLD at 5th storey



(b) Displacement of 10th storey due to TLD at 8th storey



(c) Displacement of 10th storey due to TLD at 10th storey

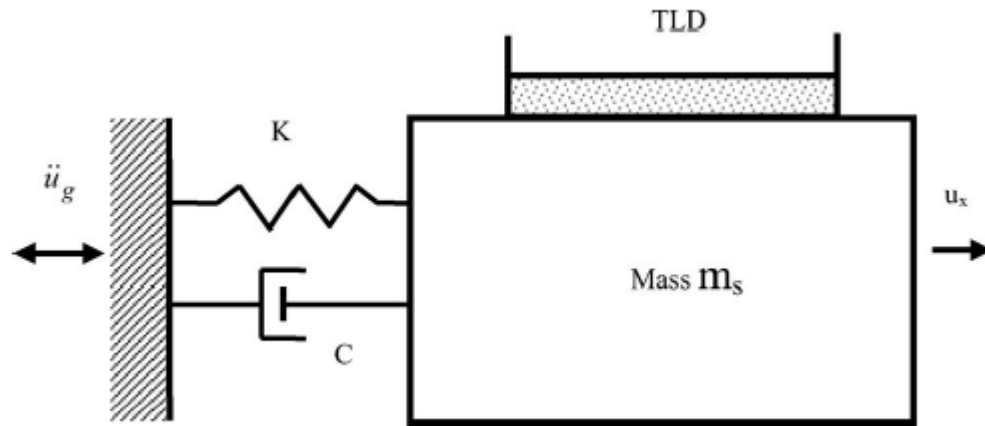
بخش دوم

(مرز دانش)

Structural vibration control using modified tuned liquid dampers

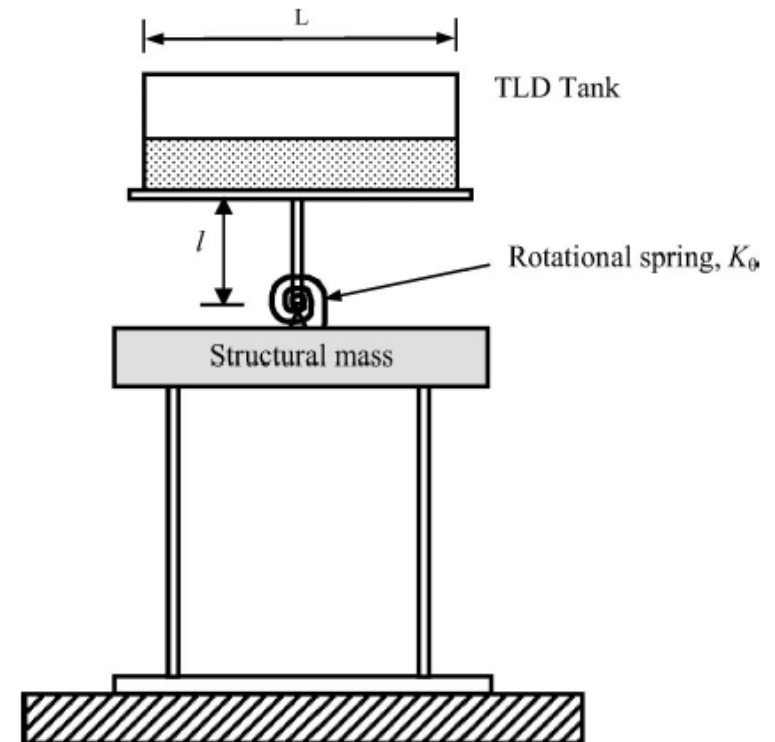
Avik Samanta a & Pradipta Banerji(2010)

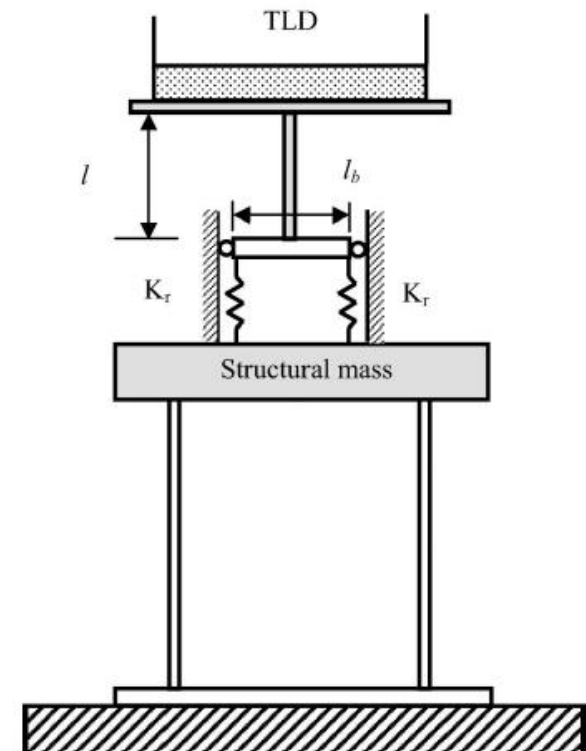
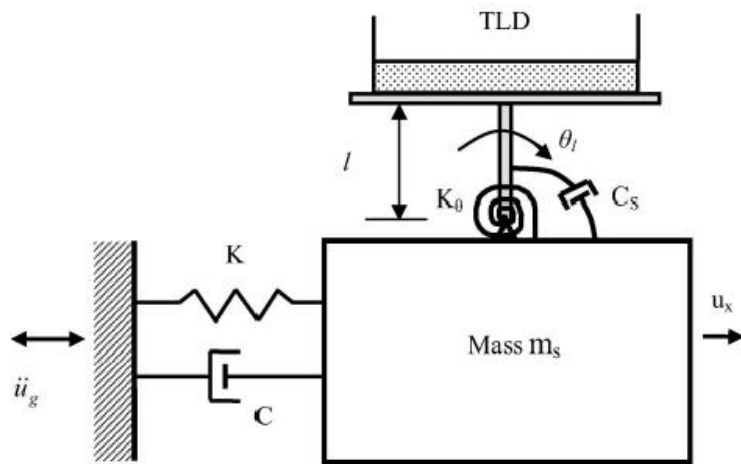
مدل استاندارد



$$m_s \ddot{u}_x + C \dot{u}_x + K u_x = -m_s \ddot{u}_g + F.$$

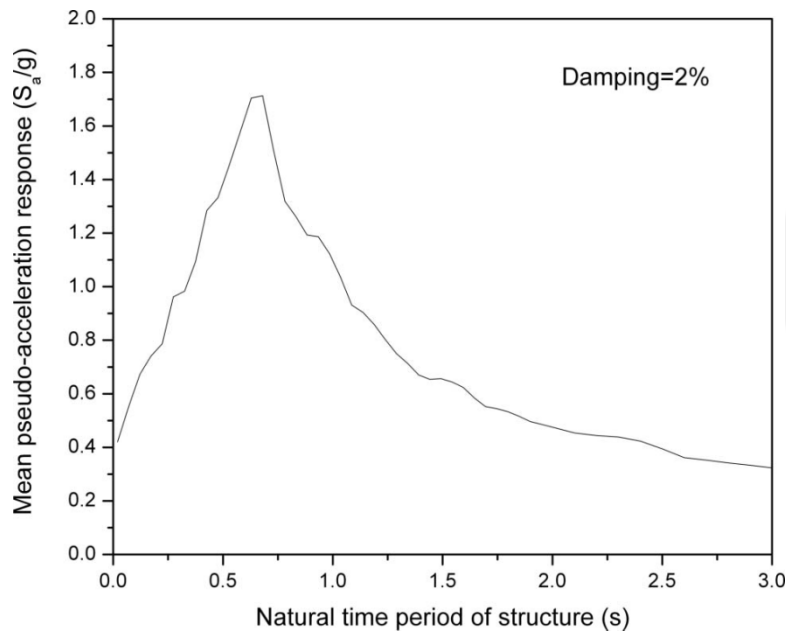
مدل اصلاح شده





$$\begin{aligned}
 & \begin{bmatrix} (m_s + m_t) & m_t \\ m_t & (m_t + (J_1 + J_2)/l^2) \end{bmatrix} \begin{Bmatrix} \ddot{u}_x \\ l \cdot \ddot{\theta}_1 \end{Bmatrix} \\
 & + \begin{bmatrix} C & 0 \\ 0 & C_s/l^2 \end{bmatrix} \begin{Bmatrix} \dot{u}_x \\ l \cdot \dot{\theta}_1 \end{Bmatrix} + \begin{bmatrix} K & 0 \\ 0 & K_\theta/l^2 \end{bmatrix} \begin{Bmatrix} u_x \\ l \cdot \theta_1 \end{Bmatrix} \\
 & = \begin{Bmatrix} F - \ddot{u}_g(m_s + m_t) \\ F + M/l - \ddot{u}_g m_t \end{Bmatrix}
 \end{aligned}$$

$$K_\theta = \frac{K_r l_b^2}{2}.$$



تعريف تحريك زمين

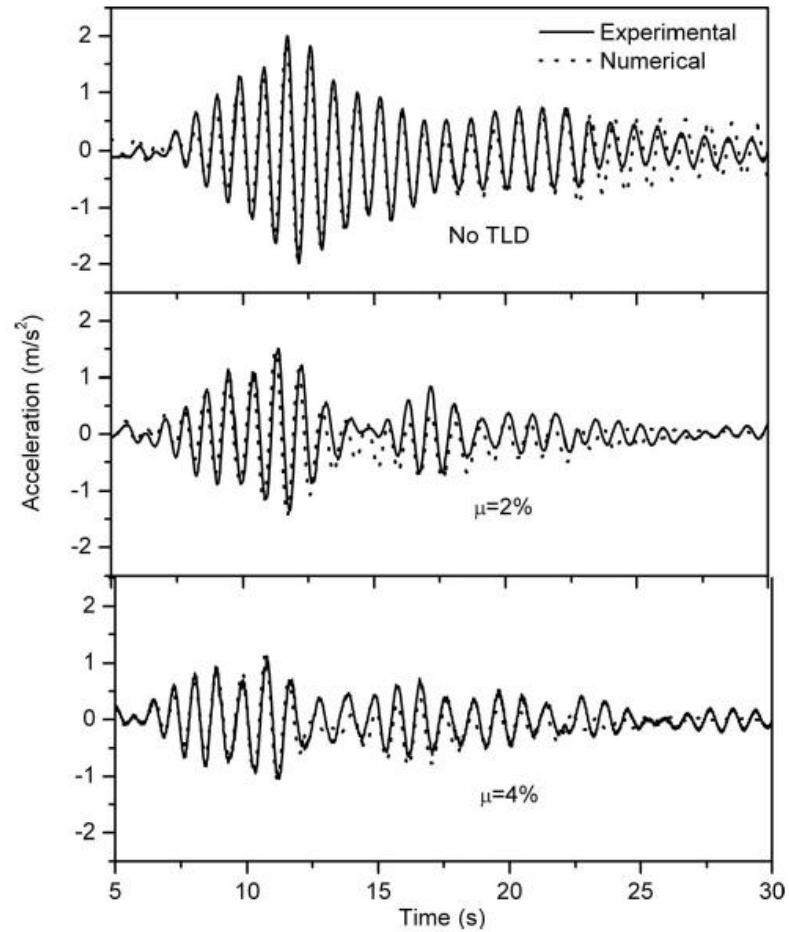
تحريك مصنوعي

تحريك هارمونيك

رکود زمين لرزه

Table 1. List of 20 far-field recorded earthquake ground motions.

Earthquake	Earthquake no.	Station name	Component (°)	PGA (g)
Loma Prieta (1989)	1	Foster City Redwood Shores	0	0.258
	2	Hayward-Bart Station	220	0.156
	3	Sago South-Hollister Cienega Rd	261	0.072
	4	Hollister-South Street and Pine Drive	0	0.369
	5	Richmond-City Hall Parking Lot	190	0.125
	6	San Francisco Bay – Dumbarton Bridge	267	0.129
	7	Woodside – Fire Station	0	0.099
	8	San Francisco International Airport	0	0.235
	9	Yerba Buena Island	0	0.029
	10	Olema – Point Reyes Ranger Station	90	0.102
Northridge (1994)	11	Agnew – Agnews State Hospital	0	0.166
	12	Camarillo	180	0.125
	13	Alhambra – Fremont School	360	0.08
	14	Los Angeles – Baldwin Hills	90	0.239
	15	Los Angeles – Hollywood Storage grounds	90	0.231
	16	Los Angeles – Obergon Park	90	0.355
	17	Mt. Wilson – Caltech Seismic Station	90	0.133
	18	Pacoima – Kagel Canyon	90	0.30
	19	Rolling Hills Estates – Rancho Vista Sch.	90	0.116
	20	San Pedro – Palos Verdes	90	0.095



Percentage reduction in mean PSA

$\mu = 2\%$

$\mu = 4\%$

Structure and TLD properties

Experiment

Numerical

Experiment

Numerical

$f_s = 1.11$ Hz
 Depth ratio,
 $\Delta = 0.15$

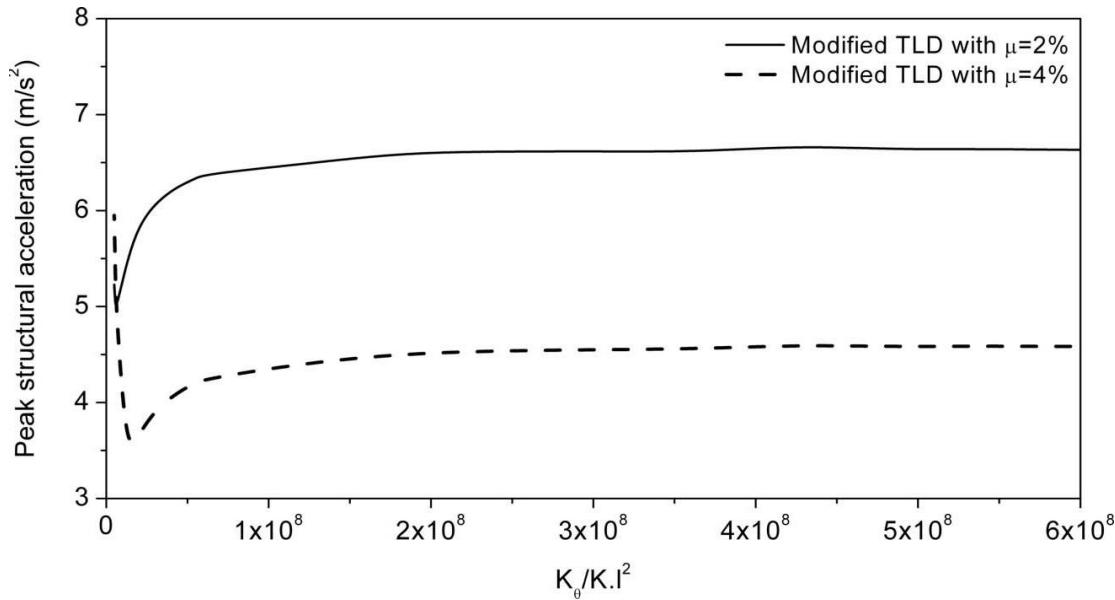
29.8

27.5

38.1

34.5

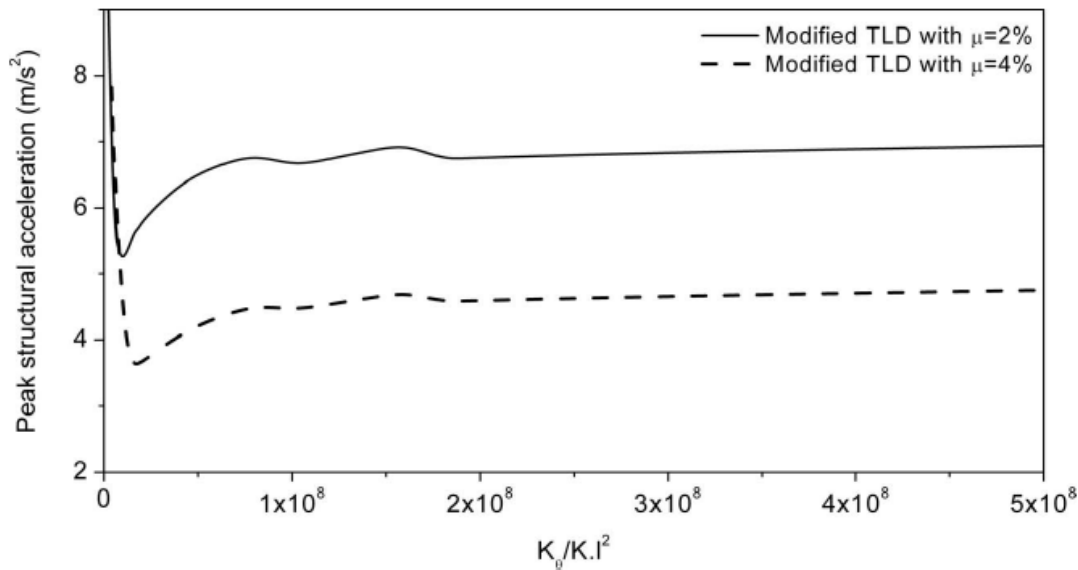
نتایج



$$f_s = 1.5 \text{ Hz}$$

$$\xi = 2\%$$

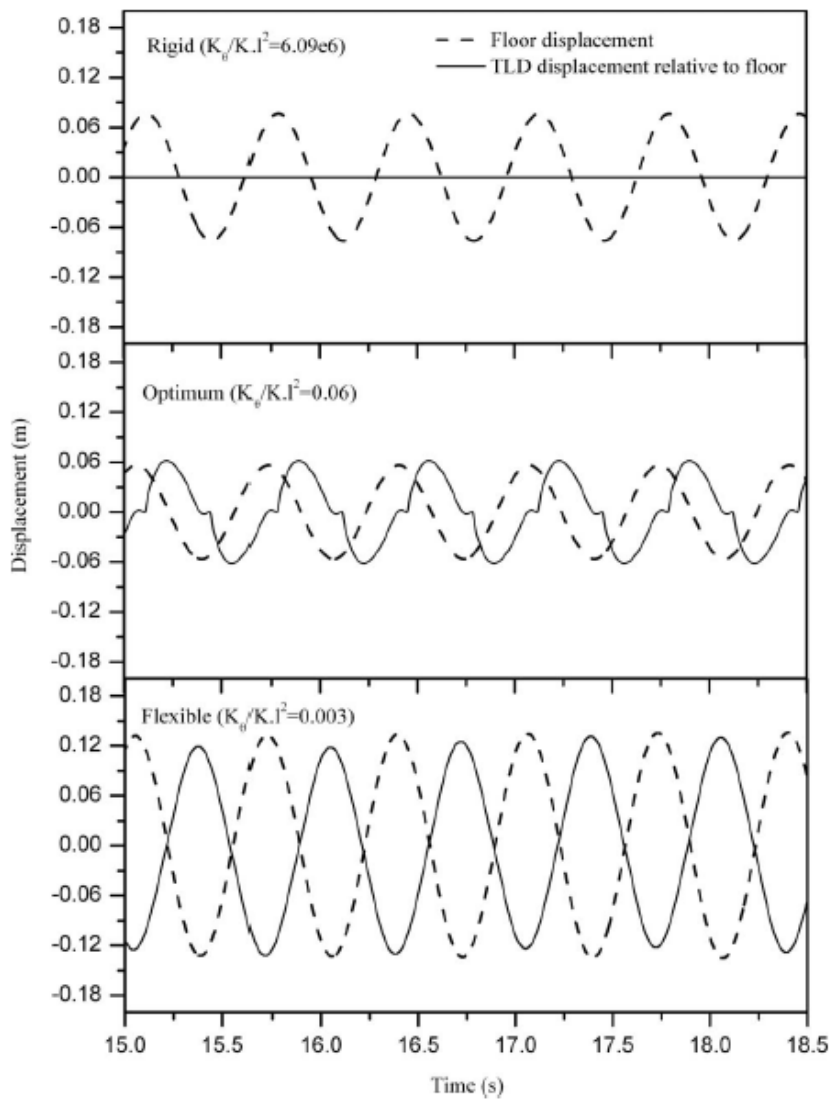
$$a_g = 0.5 \text{ m/s}^2$$



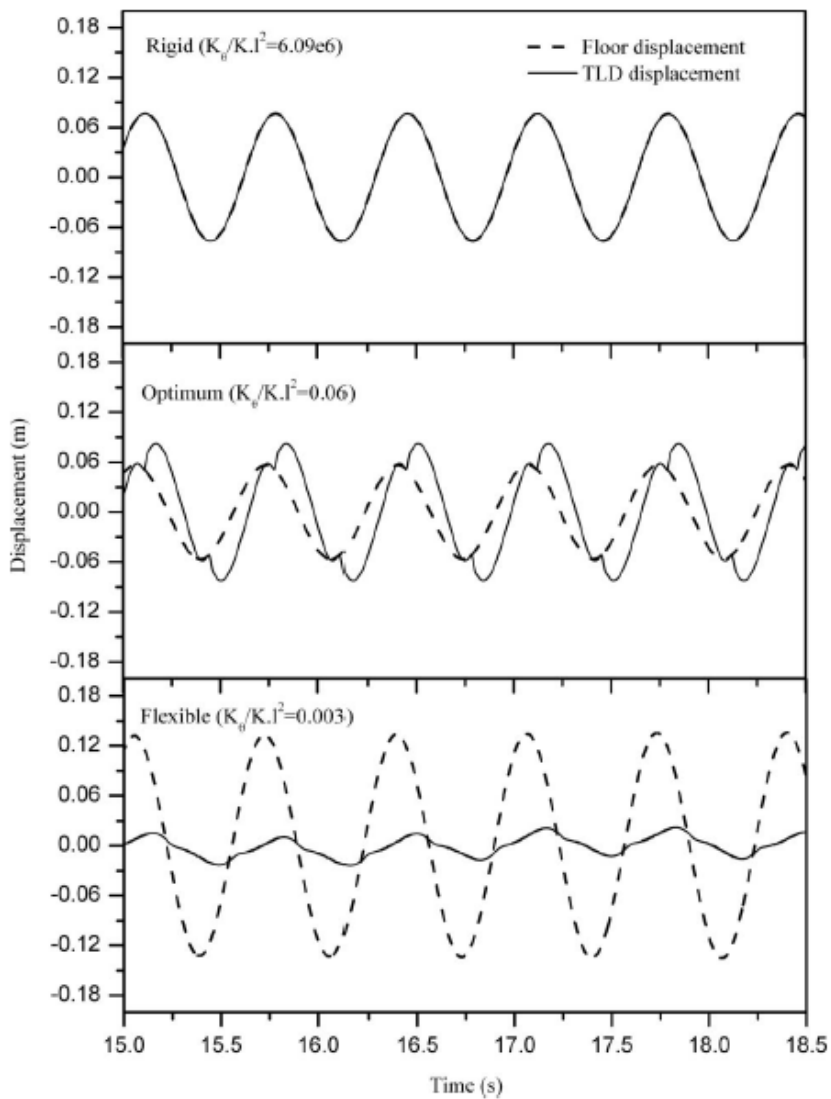
$$f_s = 0.67 \text{ Hz}$$

$$\xi = 2\%$$

$$a_g = 0.5 \text{ m/s}^2$$



تغییر مکان سقف و تغییر مکان نسبی TLD



تغییر مکان سقف و تغییر مکان TLD

نتایج

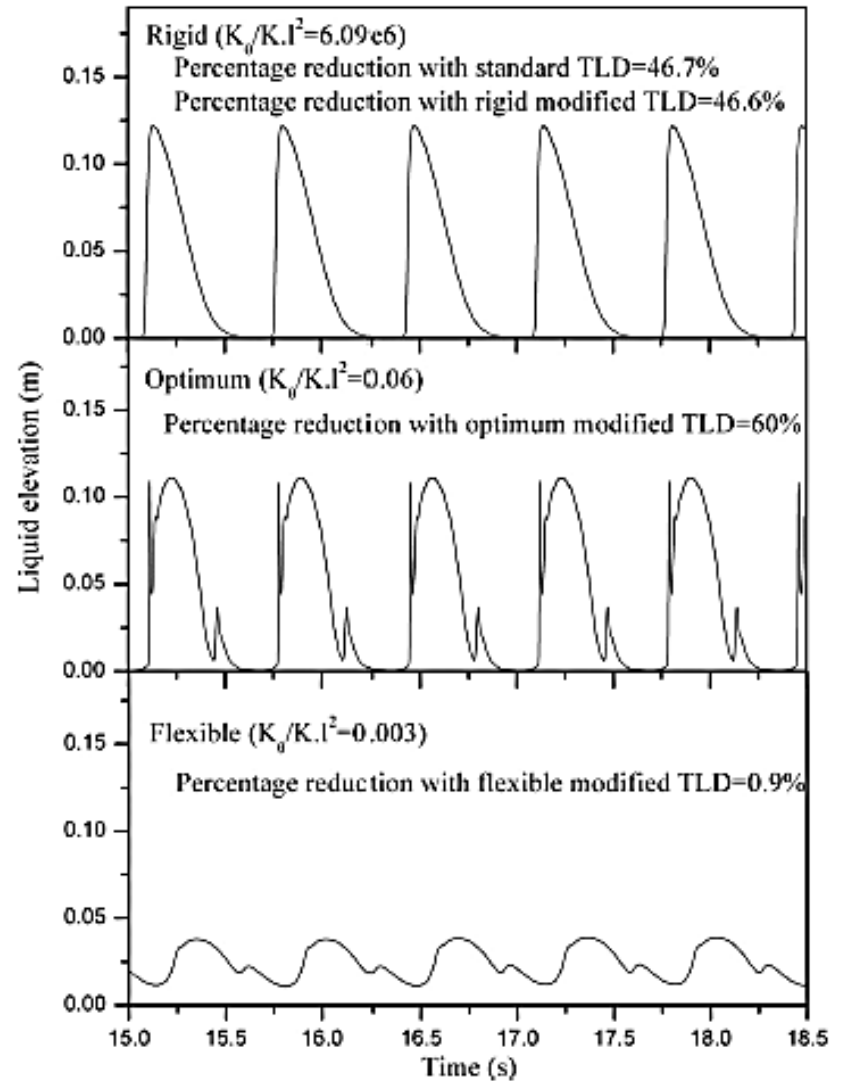
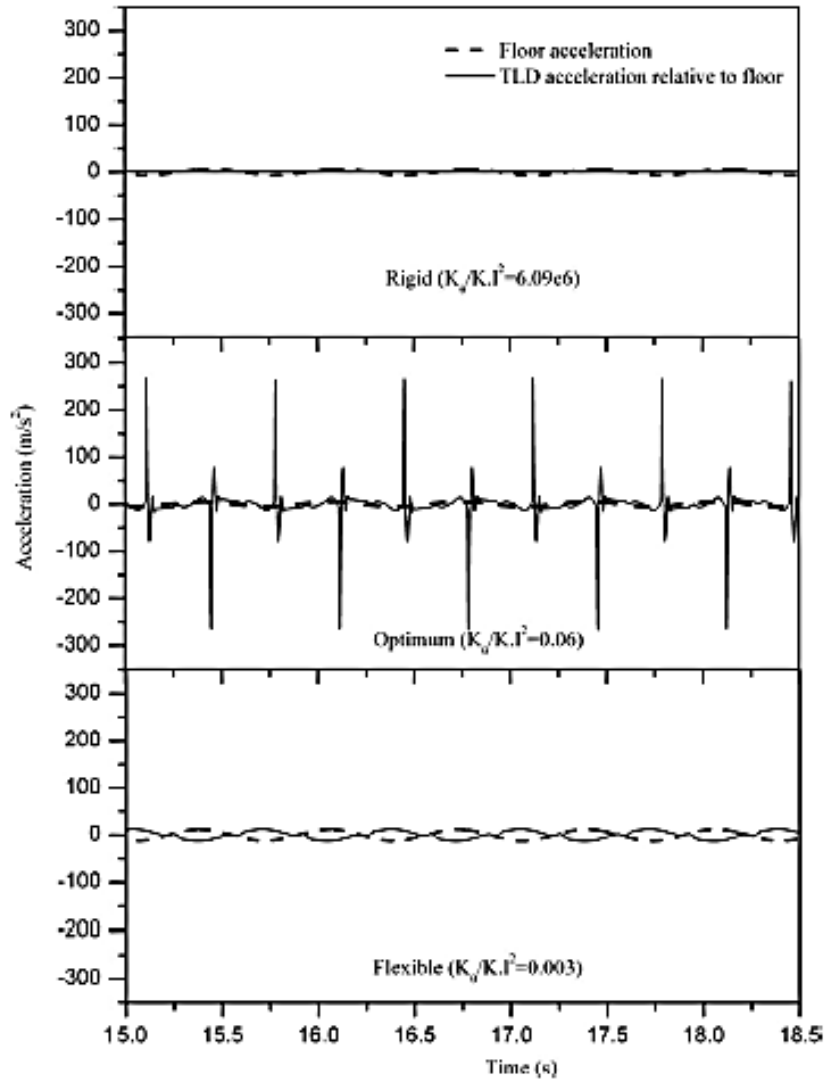


Table 3. PSAs for different structures ($\xi_s = 2\%$) under harmonic excitation (base acceleration amplitude = 0.5 m/s^2) at resonant frequency and comparison of percentage reduction in them by standard and modified TLDs.

Structure frequency (Hz)	Peak acceleration without TLD, a_{\max} (m/s^2)	Percentage reduction in a_{\max} by standard TLD		Percentage reduction in a_{\max} by optimally designed modified TLD			
		$\mu = 2\%$	$\mu = 4\%$	$\mu = 2\%$		$\mu = 4\%$	
				% Reduction	Optimum K_θ/Kl^2	% Reduction	Optimum K_θ/Kl^2
1.5	12.44	46.67	62.94	59.64	0.08	71.61	0.15
1.33	12.39	42.90	59.18	56.53	0.10	70.09	0.15
1	12.16	45.83	62.83	59.21	0.08	71.67	0.18
0.75	11.74	43.87	61.00	56.39	0.10	69.78	0.18
0.67	11.38	39.22	57.89	53.97	0.10	66.84	0.25
0.50	10.49	35.77	55.43	55.00	0.10	69.85	0.25

Table 4. PSAs for different structures ($\xi_s = 2\%$) due to three different recorded ground motions, and comparison of percentage reduction in them by standard and modified TLDs.

Ground motion Structure frequency (Hz)	a_{max} (m/s ²)	Percentage reduction in a_{max} by standard TLD on shear-beam structure		Percentage reduction in a_{max} by optimally designed modified TLD			
		$\mu = 2\%$	$\mu = 4\%$	$\mu = 2\%$		$\mu = 4\%$	
				% Reduction	Optimum K_θ/KI^2	% Reduction	Optimum K_θ/KI^2
El Centro							
2	10.8	12.60	23.16	12.90	*	23.67	*
1.5	7.68	16.86	19.87	17.22	18.28	20.2	18.28
1.33	6.26	28.18	25.28	29.37	0.97	30.28	0.44
1	6.02	17.74	28.12	21.63	0.07	32.47	0.27
0.67	2.08	6.29	12.74	12.27	0.08	20.18	0.20
0.5	1.87	22.47	22.78	23.59	0.07	27.54	0.10
Dumbarton							
2	2.97	5.45	4.75	6.41	1.09	16.22	0.10
1.5	2.68	-4.87	-4.19	13.47	0.03	15.67	0.05
1.33	4.28	37.45	50.07	40.68	0.44	50.29	*
1	3.67	13.12	22.13	27.81	0.06	42.91	0.08
0.67	1.58	8.17	15.55	13.89	0.08	23.3	0.14
0.5	2.25	34.42	50.00	39.66	91.19	50.00	0.91
Mexico City							
2	1.77	20.29	16.41	20.64	2.19	29.91	0.06
1.5	2.46	22.92	36.89	23.92	12.12	36.89	3.66
1.33	1.74	7.50	9.18	10.26	0.97	9.63	*
1	2.11	19.4	17.36	19.61	1.82	17.36	0.46
0.67	3.05	12.01	0.77	20.55	0.06	29.36	0.12
0.5	9.45	20.1	31.58	58.21	0.10	63.73	0.11

*very high values of K_θ/KI^2 .

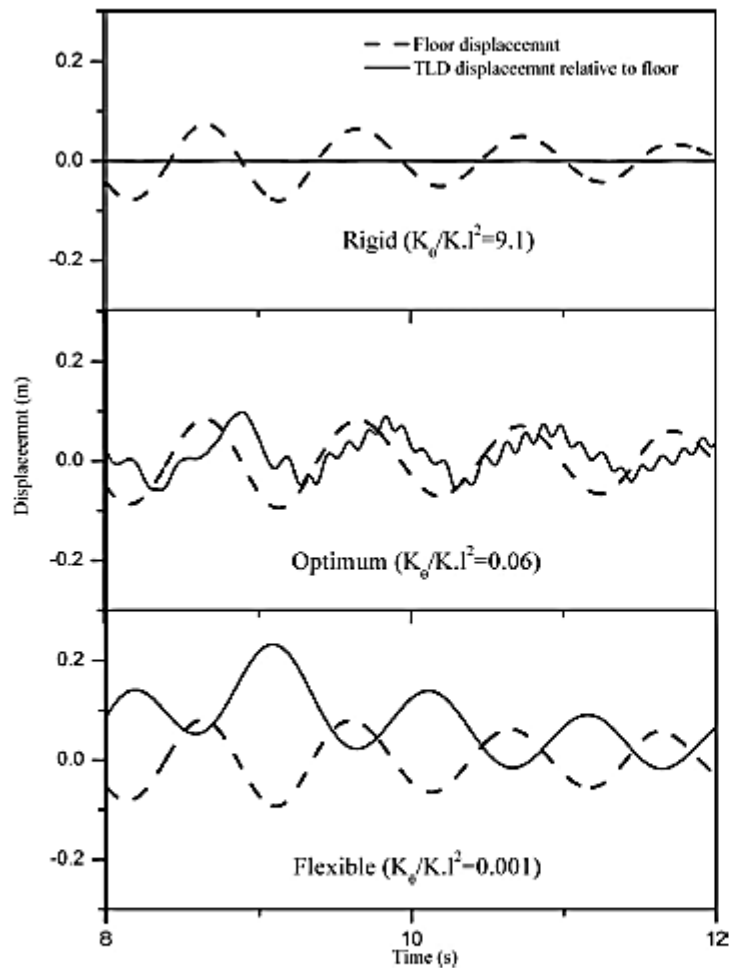


Figure 15. Time histories of floor displacement and relative displacement of TLD for a typical structure with different modified-TLDs under Dumbarton ground motion (structure: $f_s = 1$ Hz, $\xi_s = 2\%$).

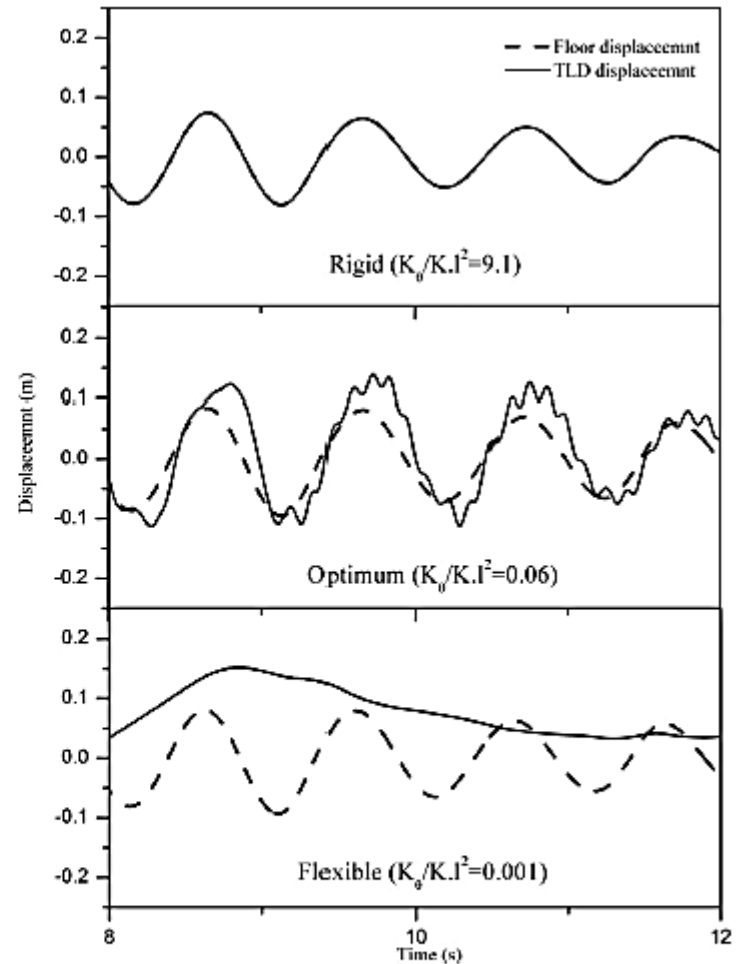


Figure 16. Time histories of floor displacement and displacement of TLD for a typical structure with different modified-TLDs under Dumbarton ground motion (structure: $f_s = 1$ Hz, $\xi_s = 2\%$).

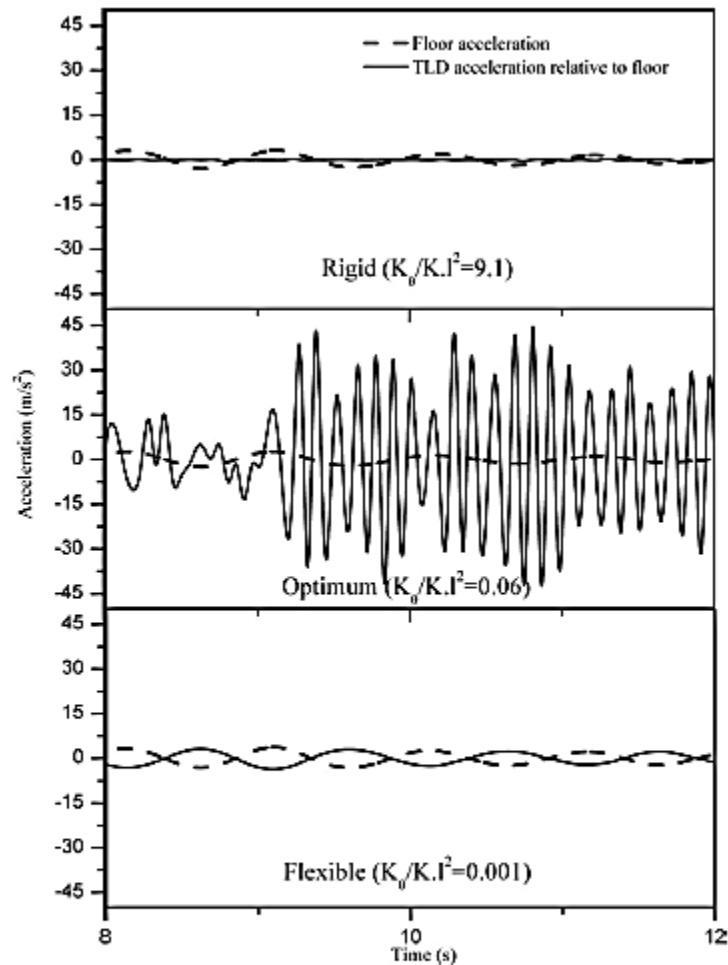


Figure 17. Time histories of floor acceleration and TLD acceleration relative to the structure for a typical structure with different modified-TLDs under Dumbarton ground motion (structure: $f_s = 1$ Hz, $\xi_s = 2\%$).

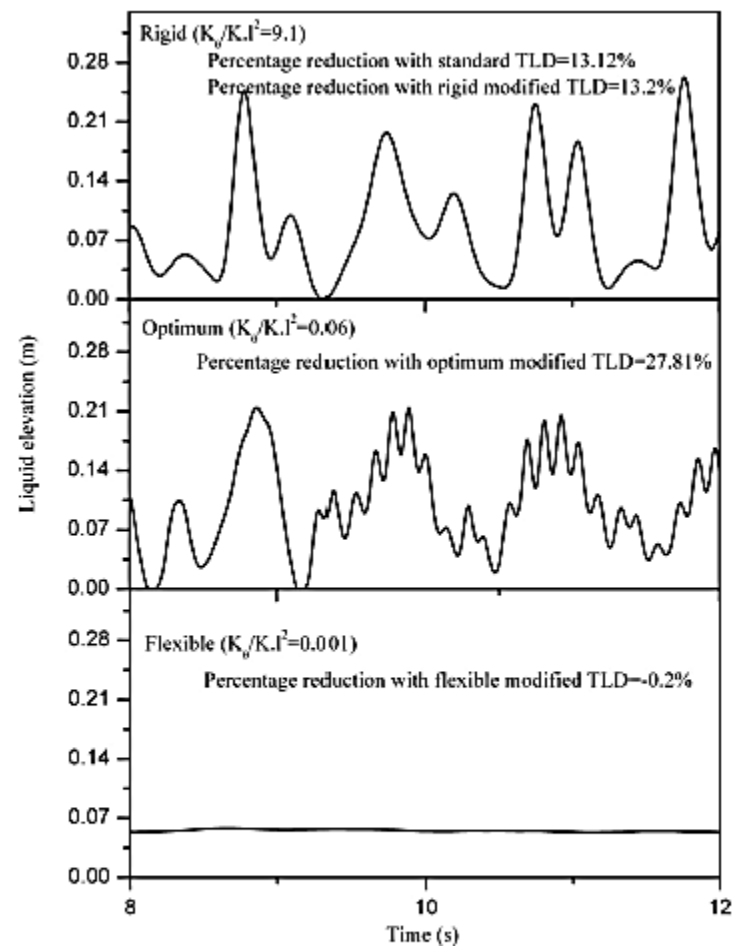


Figure 18. Plot of TLD liquid elevation time histories near right end wall for different modified-TLD under Dumbarton ground motion (structure: $f_s = 1$ Hz, $\xi_s = 2\%$, Depth of liquid = 0.053 m).

Table 5. PSAs for a typical structure ($f_s = 1$ Hz, $\xi_s = 2\%$), due to normalised far field earthquake motions, and comparison of reduction in them by standard and modified TLDs.

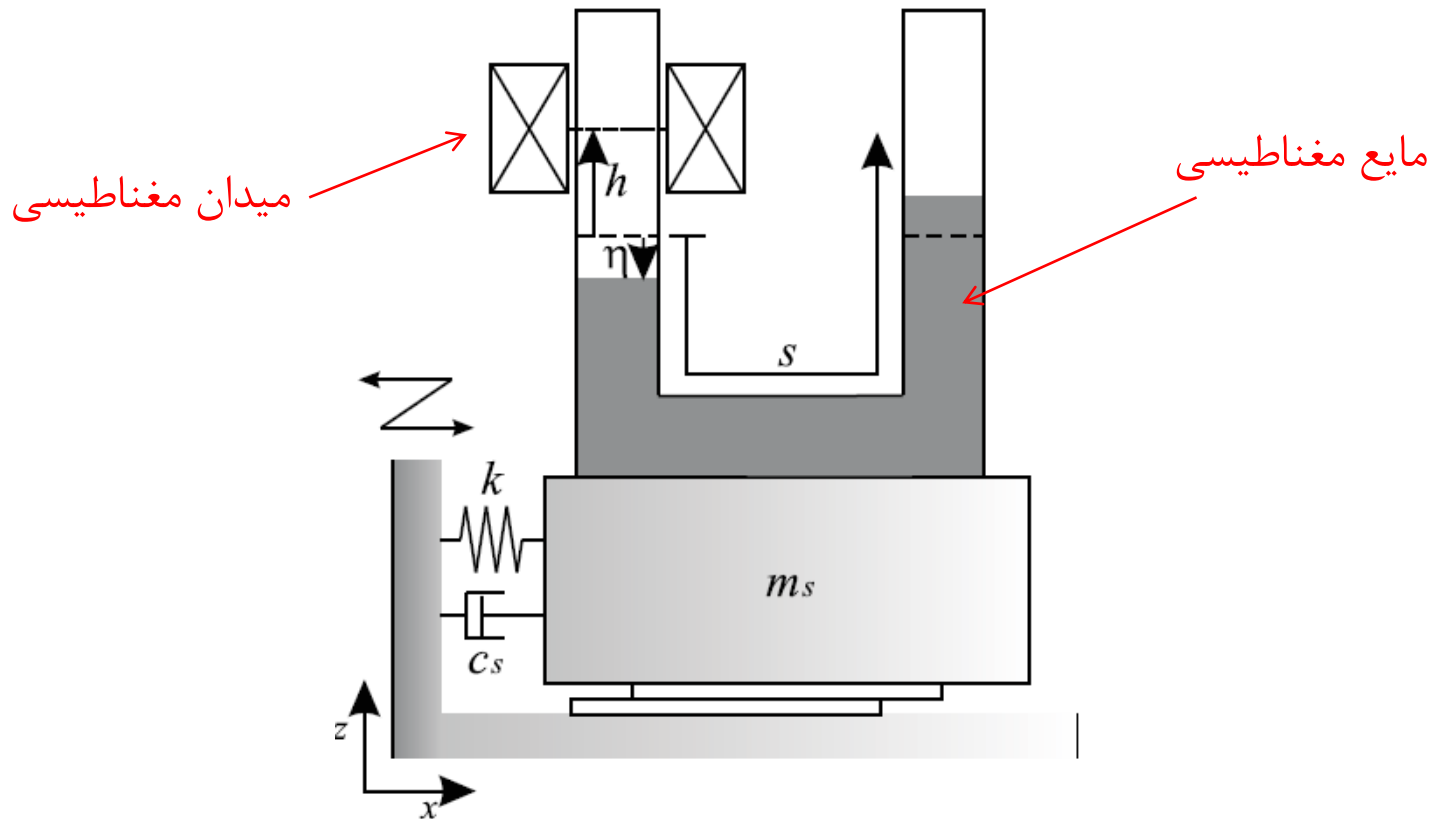
Equation no.	a_{\max} (m/s ²)	Percentage reduction in a_{\max} by standard TLD on shear-beam structure		Percentage reduction in a_{\max} by optimally designed modified TLD			
		$\mu = 2\%$	$\mu = 4\%$	$\mu = 2\%$		$\mu = 4\%$	
				% Reduction	Optimum K_{θ}/Kl^2	% Reduction	Optimum K_{θ}/Kl^2
1	8.39	11.21	7.04	22.36	0.09	35.00	0.18
2	13.19	36.70	43.76	36.62	*	46.76	0.37
3	10.17	9.50	11.47	10.04	*	13.29	0.82
4	11.05	12.27	22.33	12.11	*	21.78	*
5	15.39	20.40	32.30	21.83	0.27	32.84	*
6	9.97	15.38	21.06	24.86	0.09	31.99	0.18
7	12.24	20.12	36.48	56.90	0.36	37.28	*
8	7.05	22.95	36.05	24.08	*	38.96	0.27
9	7.73	29.16	39.95	31.78	0.36	42.92	0.18
10	11.46	11.91	19.64	11.96	*	20.23	*
11	3.66	10.99	21.35	15.13	0.82	30.19	0.46
12	6.19	-1.19	-7.44	15.80	0.18	24.91	0.27
13	4.27	26.00	48.32	29.40	0.27	48.50	3.65
14	3.19	24.88	38.15	26.05	0.37	37.60	*
15	3.81	-5.50	-10.42	10.95	0.03	8.45	0.07
16	1.46	11.77	12.83	12.52	0.04	14.32	0.06
17	1.80	46.00	34.78	45.41	0.82	36.79	*
18	7.78	22.50	32.09	22.98	*	32.95	0.27
19	3.22	30.46	50.03	38.10	0.36	55.46	0.27
20	4.20	5.63	11.72	23.03	0.05	36.28	0.07

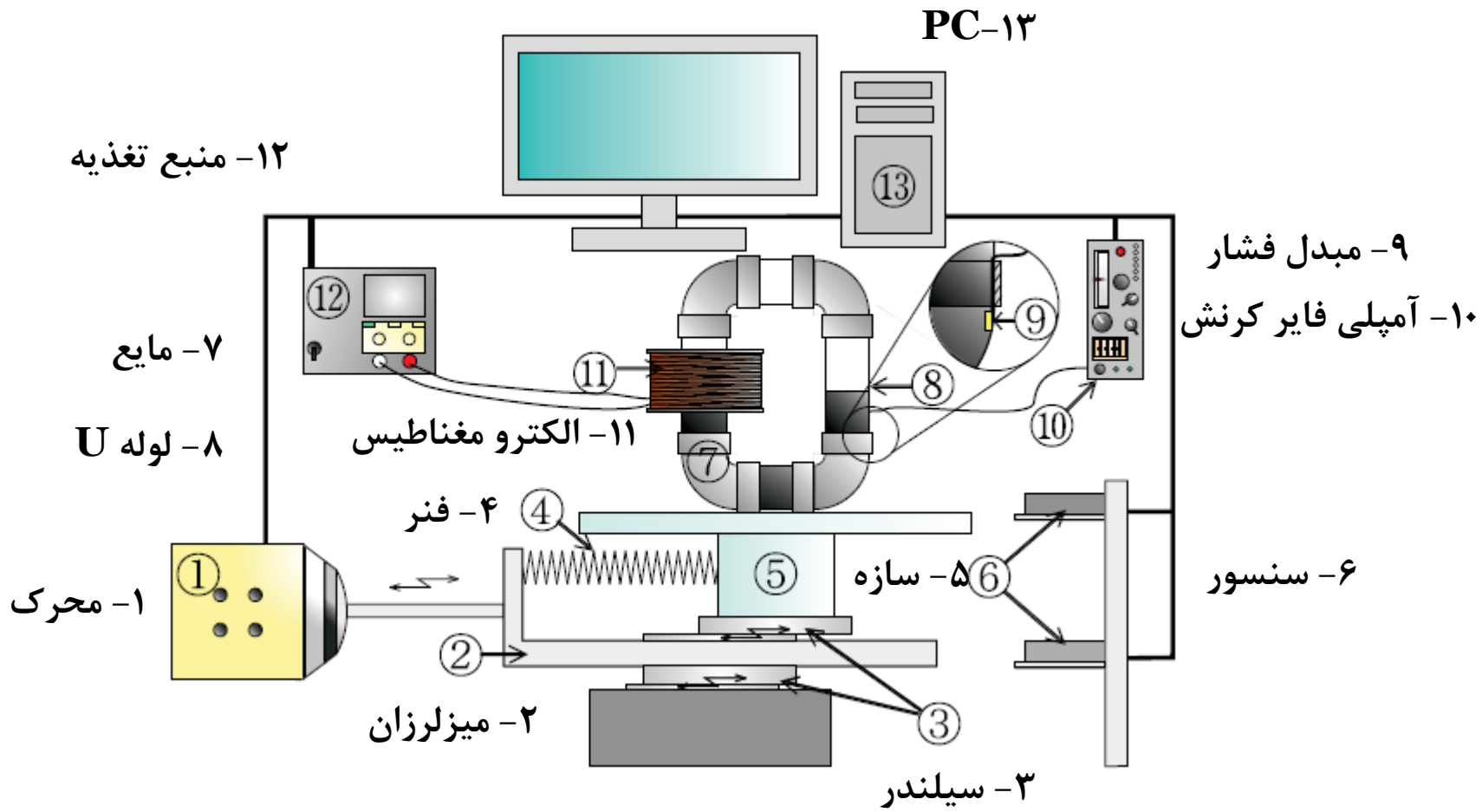
*very high values of K_{θ}/Kl^2 .

Experimental study on damping characteristics of the tuned liquid column damper with magnetic fluid

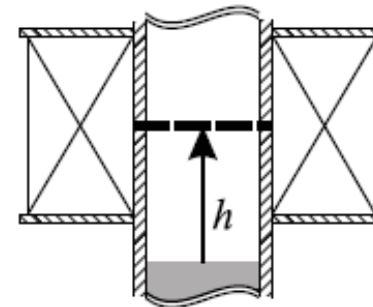
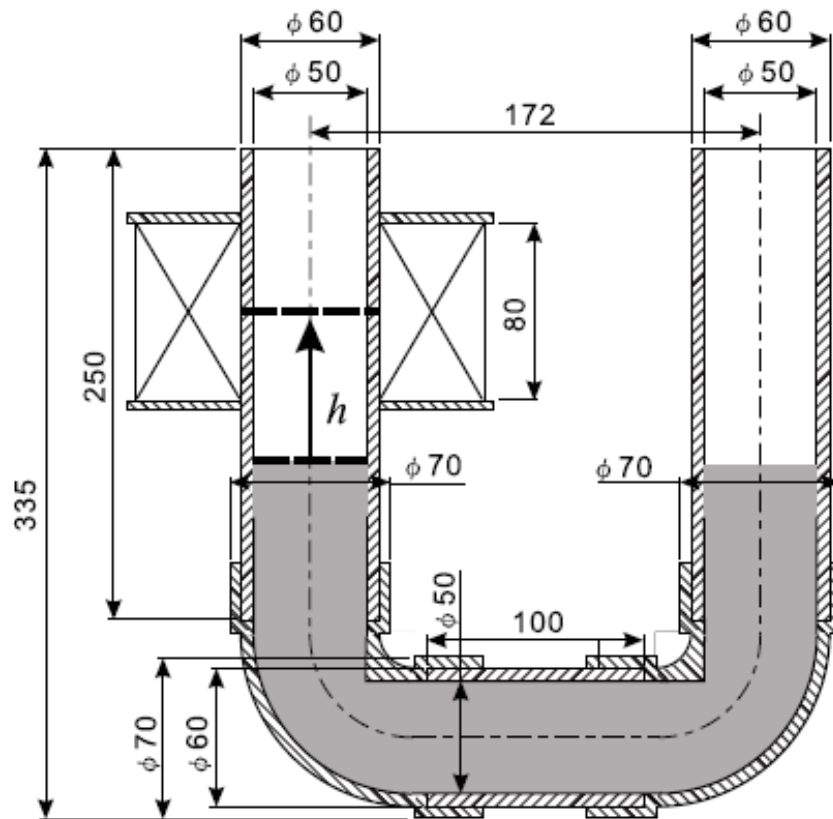
H Masuda, T Oyamada and T Sawada¹(2013) میدان مغناطیسی

tuned liquid column damper with a magnetic fluid (MF-TLCD)

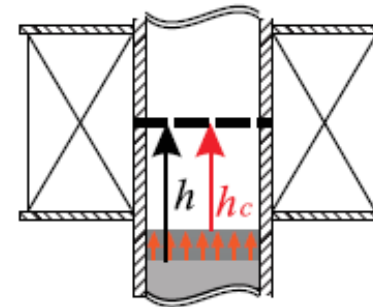




جزئیات TLCD و مایع مغناطیسی



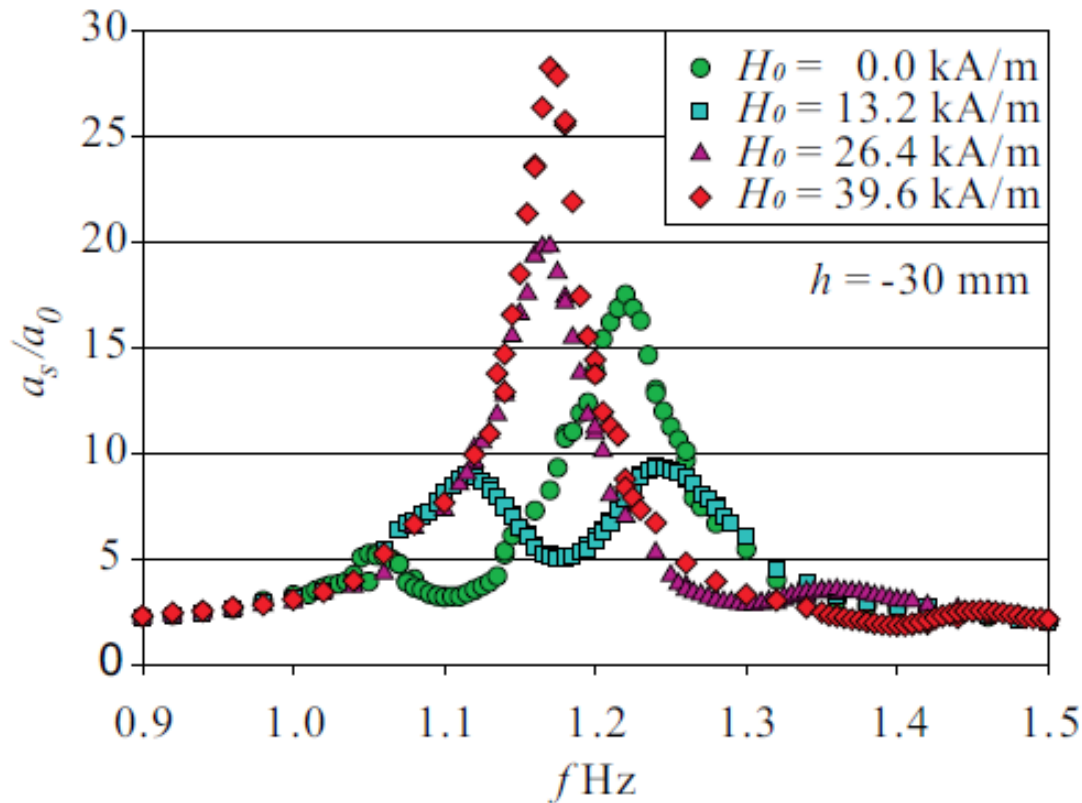
Without magnetic fields



Under a magnetic field

Density (25°C)	1350 kg/m ³
Viscosity (25°C)	5.34 mPa·s
Saturation magnetization	48 ± 5 kA/m

نتایج



دامنه سازه : a_s

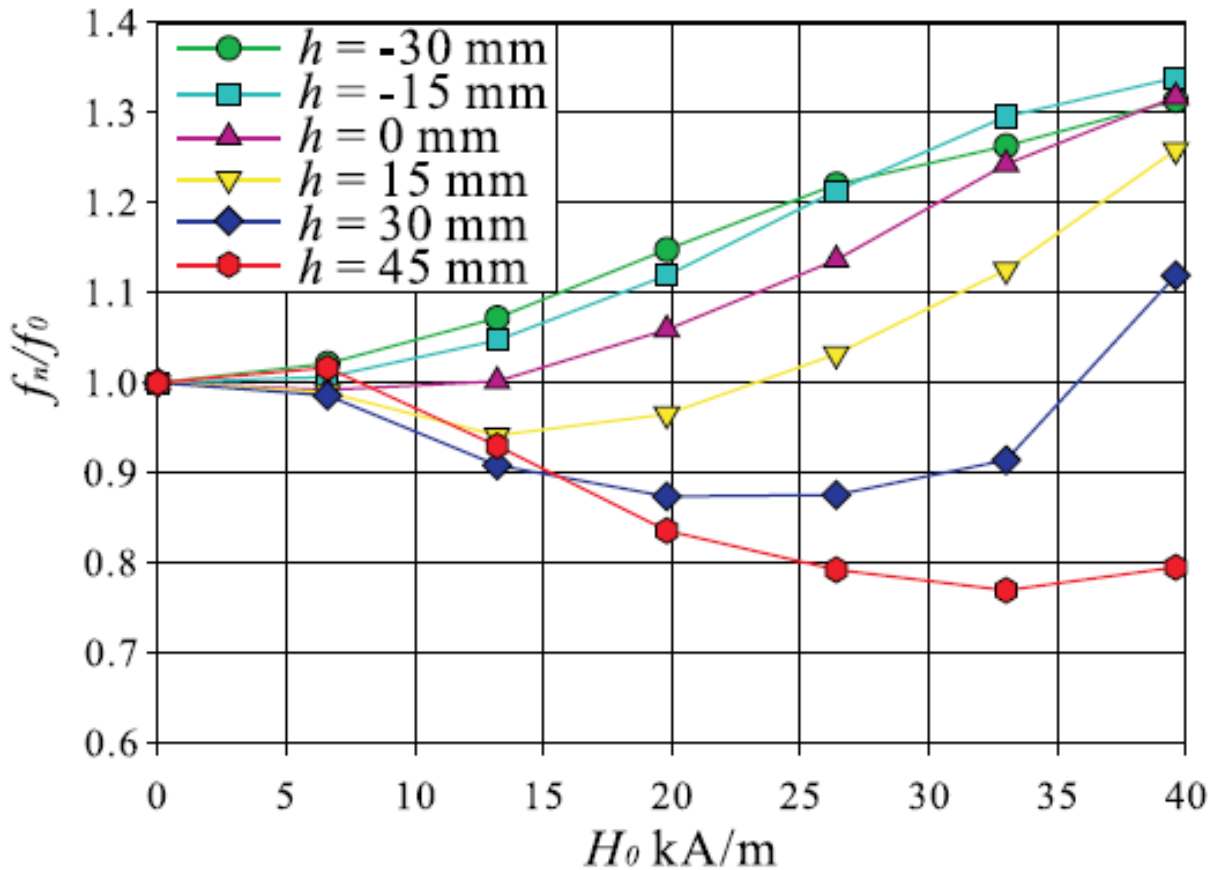
دامنه تحریک : a_0

فرکانس تحریک : f

شدت میدان مغناطیسی : H_0

. Frequency responses of dimensionless structure amplitude.

نتایج



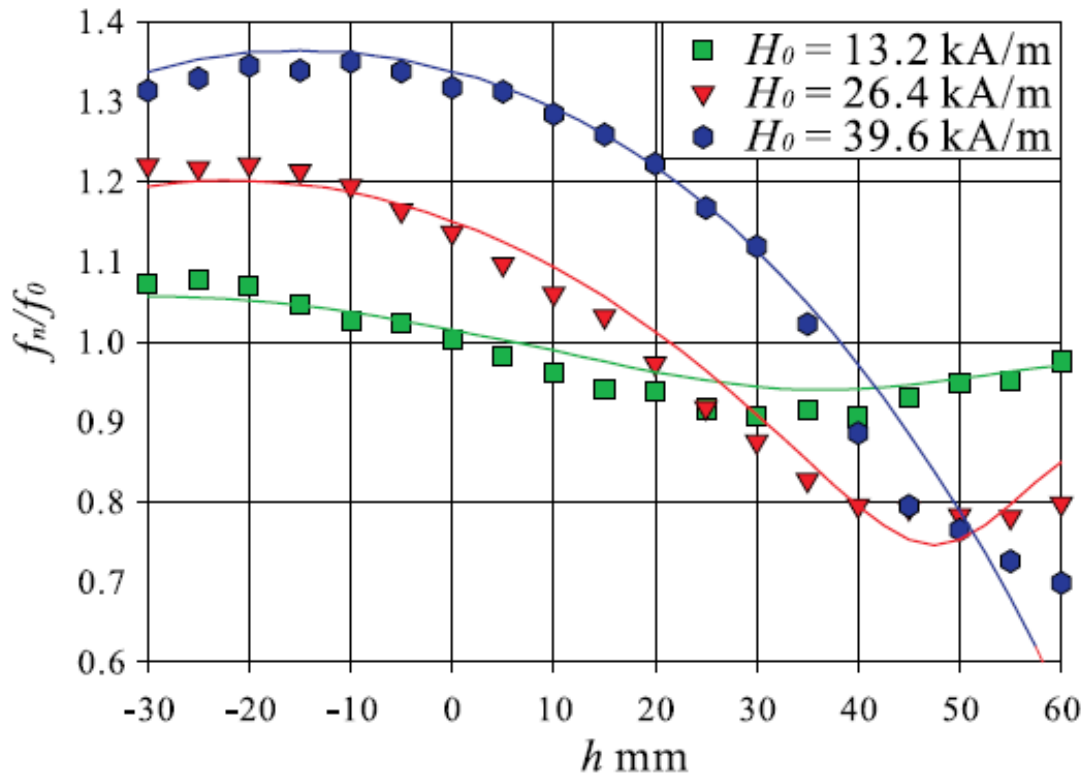
f_n : فرکانس طبیعی

f_0 : فرکانس طبیعی در غیاب میدان مغناطیسی

h : موقیعت میدان مغناطیسی از سطح آزاد مایع

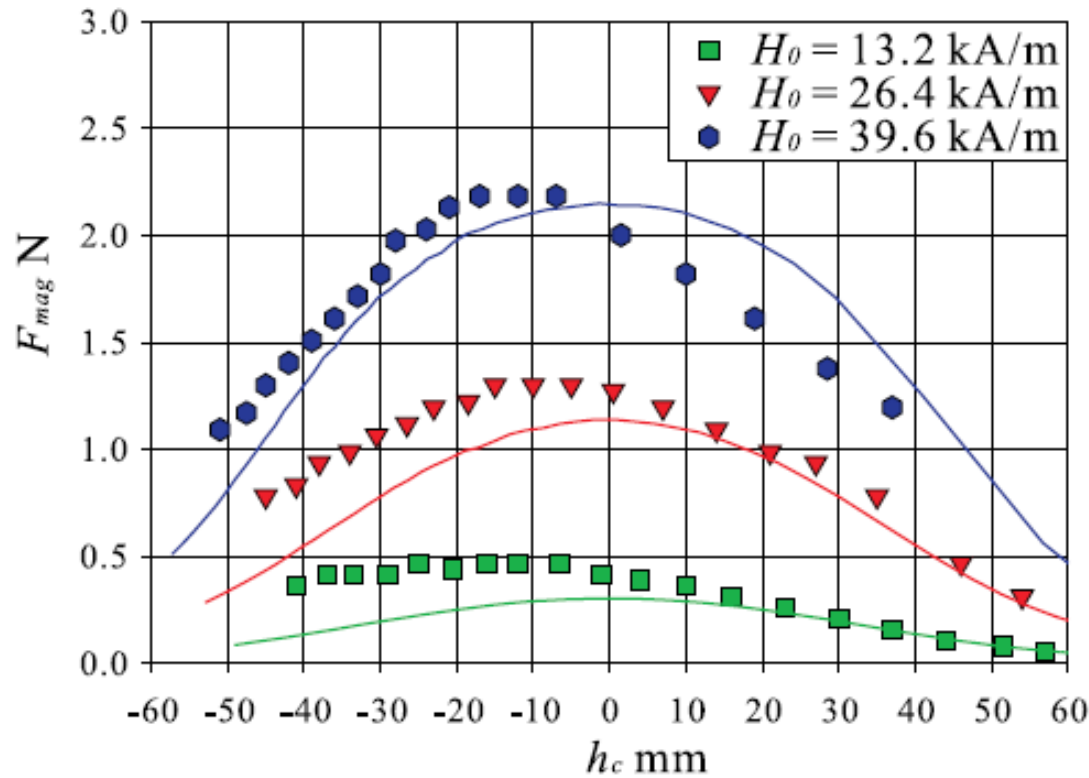
H_0 : شدت میدان مغناطیسی

$$\rho A l \ddot{\eta} + 2\rho A g \eta + \frac{1}{2} A \mu_0 \chi \left[\{H(\eta)\}^2 - \left\{ H \left(\frac{l-b}{2} \right) \right\}^2 \right] = 0$$



سمبل : نتایج آزمایشگاهی
خطوط: نتایج عددی

. Distributions of the natural frequency with h for various values of H_0 .



Summations of magnetic attraction forces acting on the magnetic fluid in the

OPTIMIZED TUNED LIQUID COLUMN DAMPERS FOR EARTHQUAKE OSCILLATIONS OF HIGH-RISE STRUCTURES INCLUDING SOIL EFFECTS

A. Farshidianfar, and S. Soheili(2013)

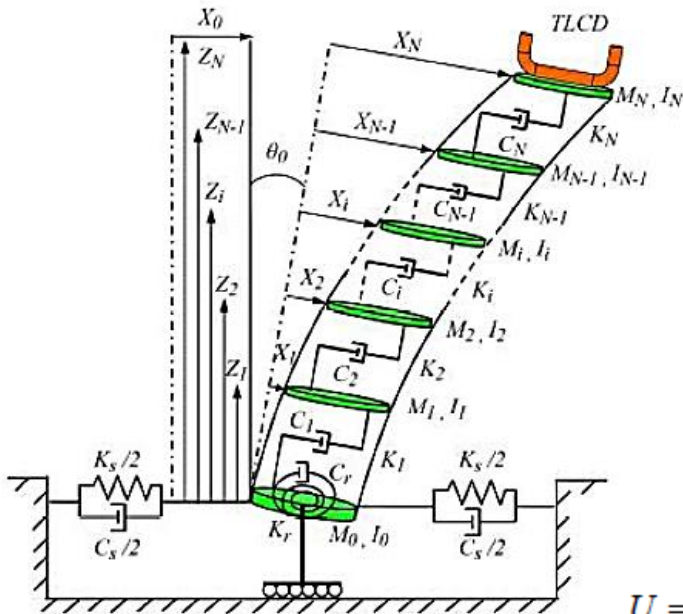
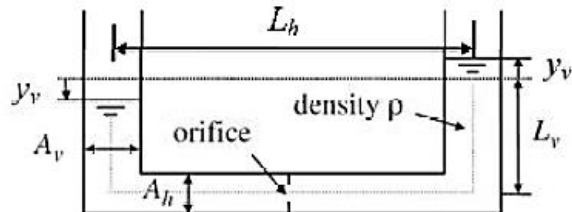


Figure 1. Shear building configuration



انرژی جنبشی

$$T = (1/2)M_0\dot{X}_0^2 + (1/2)I_0\dot{\theta}_0^2 + (1/2)M_1(\dot{X}_0 + Z_1\dot{\theta}_0 + \dot{X}_1)^2 + (1/2)I_1\dot{\theta}_1^2 + (1/2)M_2(\dot{X}_0 + Z_2\dot{\theta}_0 + \dot{X}_2)^2 + (1/2)I_2\dot{\theta}_2^2 + \dots + (1/2)M_N(\dot{X}_0 + Z_N\dot{\theta}_0 + \dot{X}_N)^2 + (1/2)I_N\dot{\theta}_N^2 + \rho A_v L_v \dot{y}_v^2 + \rho A_v L_v (\dot{X}_0 + Z_N\dot{\theta}_0 + \dot{X}_N)^2 + (1/2)\rho A_h L_h (\dot{X}_0 + Z_N\dot{\theta}_0 + \dot{X}_N + \dot{y}_h^2)^2 \quad (1)$$

انرژی پتانسیل

$$U = (1/2)K_s X_0^2 + (1/2)K_r \theta_0^2 + (1/2)K_1 X_1^2 + (1/2)K_2 (X_2 - X_1)^2 + \dots + (1/2)K_N (X_N - X_{N-1})^2 + \rho g A_v (L_v + y_v^2) \quad (2)$$

Table 1. Structure parameters [18]

No. of stories	40
Storey height (Z_i)	4 m
Storey mass (M_i)	9.8×10^5 kg
Storey moment of inertia (I_i)	1.31×10^8 kgm ²
	$K_1 = 2.13 \times 10^9$ N/m
Storey stiffness	$K_{40} = 9.98 \times 10^8$ N/m
	$K_{40} \leq K_i \leq K_1$
Foundation radius (R_0)	20 m
Foundation mass (M_0)	1.96×10^6 kg
Foundation moment of inertia (I_0)	1.96×10^8 kgm ²

Table 2. Parameters of the soil and foundation [18]

Soil Type	Swaying damping C_s (Ns/m)	Rocking damping C_r (Nsm)	Swaying stiffness K_s (N/m)	Rocking stiffness K_r (N/m)
Soft Soil	2.19×10^8	2.26×10^{10}	1.91×10^9	7.53×10^{11}
Medium Soil	6.90×10^8	7.02×10^{10}	1.80×10^{10}	7.02×10^{12}
Dense Soil	1.32×10^9	1.15×10^{11}	5.75×10^{10}	1.91×10^{13}

Table 3. Natural and damped frequencies of the structure

ω (rad/s)		ω_1	ω_2	ω_3
Soft soil	With Damping	-0.02 ± 1.08	-0.24 ± 4.45	-0.62 ± 7.42
	Without Damping	1.09	4.44	7.40
Medium soil	With Damping	-0.02 ± 1.54	-0.21 ± 4.57	-0.58 ± 7.55
	Without Damping	1.54	4.58	7.58
Dense soil	With Damping	-0.02 ± 1.60	-0.21 ± 4.58	-0.58 ± 7.57
	Without Damping	1.61	4.59	7.59
Fixed base	With Damping	-0.03 ± 1.64	-0.21 ± 4.59	-0.58 ± 7.58
	Without Damping	1.65	4.60	7.60

Table 4. The parameter settings for TLCD

$0.1(m) \leq l_e \leq 33.1(m)$
$0 \leq \eta \leq 51$
$0.01 \leq r \leq 3.01$
$0.01 \leq n \leq 0.51$

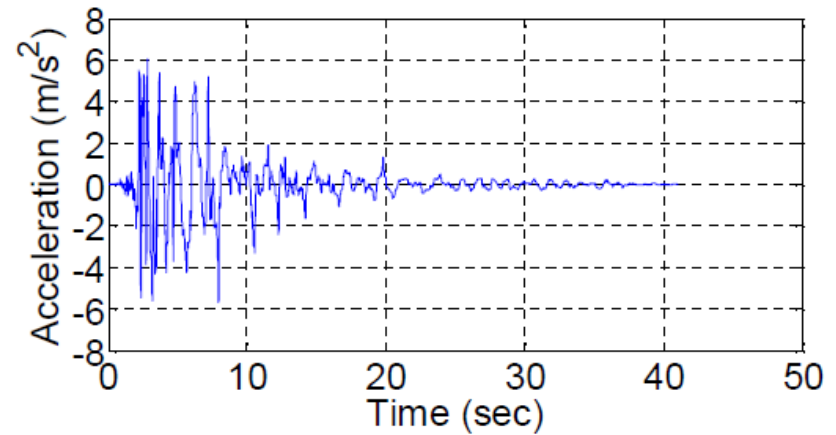
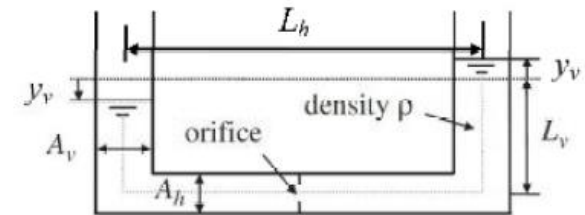


Figure 3. Kobe earthquake acceleration spectrum

Table 5. The optimized TLCD parameters

Soil type	Best values		Absolute Values		RMS values	
			u_{max}	\ddot{u}_{max}	u_{max}	\ddot{u}_{max}
Soft soil	l_e (m)		0.7	0.7	1.6	0.7
	$l_e=0.7$	n	0.30	0.01	0.01	0.01
	(m)	r	0.21	0.81-1.01	2.61-3.01	0.61
	$l_e=1.6$	n	0.51	0.11	0.01	0.51
	(m)	r	0.01	1.41-1.81	1.21-1.81	0.01
Medium soil	l_e (m)		0.7	0.7	9.4	0.7
	$l_e=0.7$	n	0.11	0.19	0.01	0.01
	(m)	r	0.61-0.81	0.81-1.21	0.81-1.21	0.61
	$l_e=9.4$	n	0.01	0.51	0.01	0.09
	(m)	r	1.01	0.01	3.01	0.01
Dense soil	l_e (m)		0.7	0.7	9.1	0.7
	$l_e=0.7$	n	0.09	0.25	0.01	0.01
	(m)	r	0.61-0.81	1.01-1.21	0.81-1.01	0.61-0.81
	$l_e=9.1$	n	0.01	0.51	0.01	0.11
	(m)	r	1.01	0.01	3.01	0.01
Fixed base	l_e (m)		0.7	0.7	8.5	0.7
	$l_e=0.7$	n	0.09	0.29	0.01	0.01
	(m)	r	0.61	1.01-1.21	0.81-1.01	0.61-0.81
	$l_e=8.5$	n	0.01	0.51	0.01	0.13
	(m)	r	0.81-1.01	0.01	3.01	0.01
Single DOF structure	l_e (m)		7.0-8.5	8.8-11.5	7.9-8.5	7.6-8.8
	$l_e=8$	n	0.01	0.01	0.01	0.01
	(m)	r	0.41-0.61	0.81	0.61	0.61-0.81
	$l_e=11$	n	0.01	0.01	0.01	0.01
	(m)	r	0.81	0.81-1.01	1.01	1.01-1.41

نتایج



$$l_e = 2L_v + rL_h$$

$$n = \frac{L_v}{L_h}$$

$$r = \frac{A_v}{A_h}$$

$$\omega_{TLCD} = \sqrt{\frac{2g}{l_e}}$$

Table 6. Vibration without TLCD

Soil type	Absolute values		RMS values	
	$u_{\max} (m)$	$\ddot{u}_{\max} (m/s^2)$	$u_{\max} (m)$	$\ddot{u}_{\max} (m/s^2)$
Soft Soil	0.76	9.55	0.16	1.99
Medium Soil	1.06	11.29	0.35	2.16
Dense Soil	1.06	11.40	0.35	2.18
Fixed Base	1.06	11.44	0.35	2.19
Single DOF Structure	0.74	6.77	0.26	1.45

Table 7. Vibration with TLCD

Soil type	Best values (m)	Absolute Values		RMS values	
		%Reduction		%Reduction	
		u_{\max}	\ddot{u}_{\max}	u_{\max}	\ddot{u}_{\max}
Soft soil	$l_e=0.7$	13.11	7.57	11.57	16.83
	$l_e=1.6$	12.35	6.07	12.70	7.82
Medium soil	$l_e=0.7$	13.87	22.20	-1.03	17.26
	$l_e=9.4$	12.37	13.58	34.83	10.40
Dense soil	$l_e=0.7$	13.62	23.02	0.64	17.18
	$l_e=9.1$	12.42	12.47	31.52	10.34
Fixed base	$l_e=0.7$	13.51	23.41	5.23	17.26
	$l_e=8.5$	12.44	11.74	31.66	10.50
Single DOF structure	$l_e=8$	19.10	2.25	35.28	7.92
	$l_e=11$	15.60	2.38	34.59	7.65

An experimental study on tuned liquid damper for mitigation of structural response

Emili Bhattacharjee, Lipika Halder and Richi Prasad Sharma(2013)



Figure 1 Experimental set-up.

سقف صلب: $1 \times 1 \text{ m}$, $w=140 \text{ kg}$

ستون: $6 \times 6 \times 500 \text{ mm}$



Figure 2 TLD scale model performance test.

مشخصات TLD

Table 1 TLD parameters

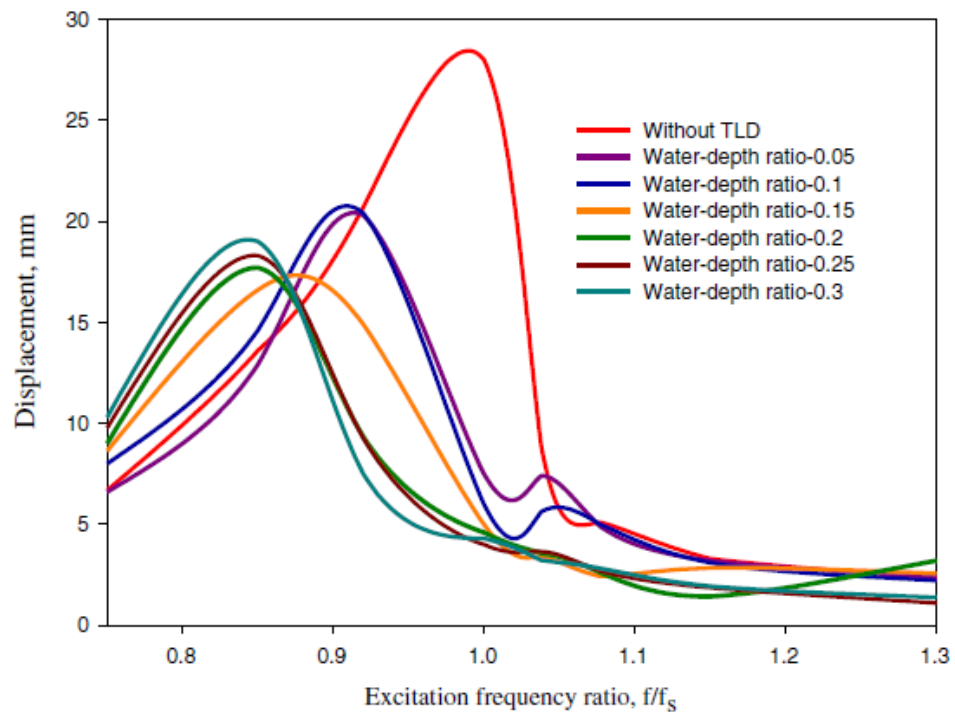
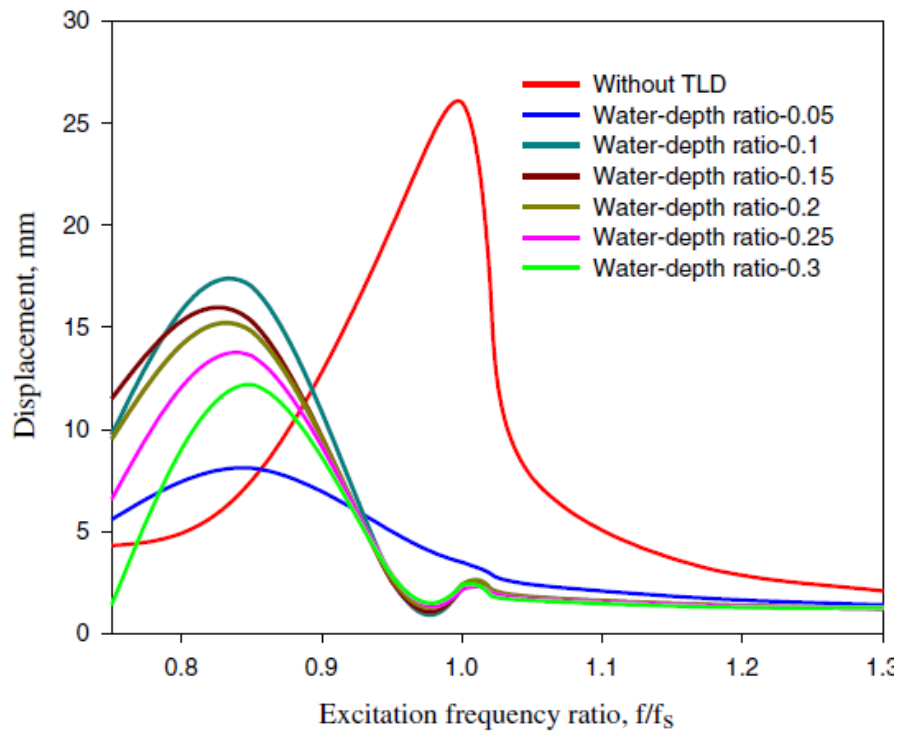
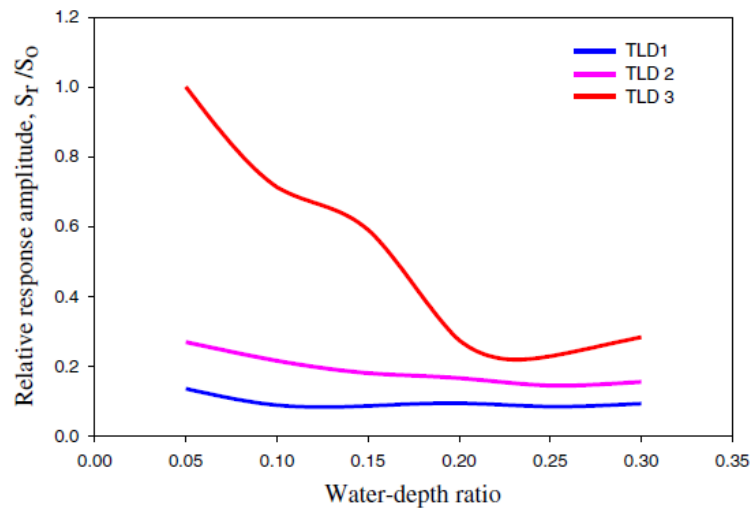
Case number	Type of TLD		Container dimensions		
	Shape	Symbol	Length (cm)	Width (cm)	Depth (cm)
Case 1	Rectangular	TLD ₁	30	20	30
Case 2	Rectangular	TLD ₂	20	30	30
Case 3	Square	TLD ₃	30	30	40

شرایط آزمایش

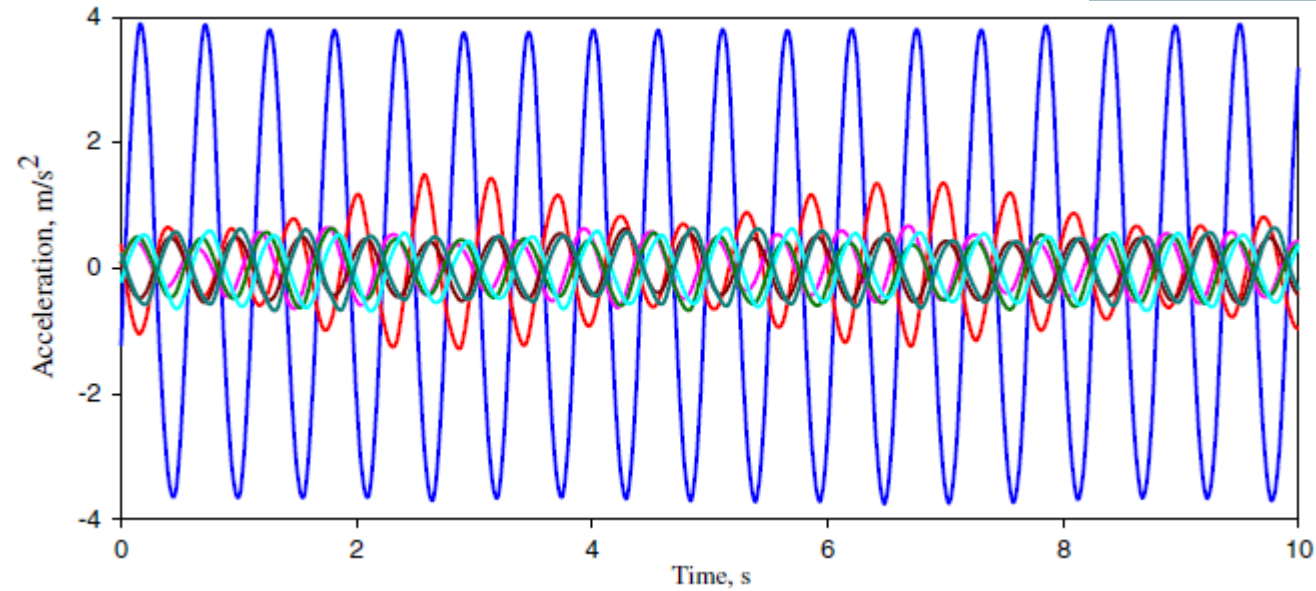
Table 2 Experimental cases

TLD type	Water depth ratio	Base displacement amplitude (mm)	External frequency (Hz)	Excitation frequency ratio (β)
TLD ₁	0.05, 0.1, 0.15, 0.2, 0.25, 0.3	3	1.4, 1.6, 1.8, 1.9, 2.0, 2.2, 2.3, 2.4	0.75, 0.85, 0.95, 1.0, 1.05, 1.15, 1.2, 1.3
TLD ₂	0.05, 0.1, 0.15, 0.2, 0.25, 0.3	3	1.4, 1.6, 1.8, 1.9, 2.0, 2.2, 2.3, 2.4	0.75, 0.85, 0.95, 1.0, 1.05, 1.15, 1.2, 1.3
TLD ₃	0.05, 0.1, 0.15, 0.2, 0.25, 0.3	3	1.4, 1.6, 1.8, 1.9, 2.0, 2.2, 2.3, 2.4	0.75, 0.85, 0.95, 1.0, 1.05, 1.15, 1.2, 1.3

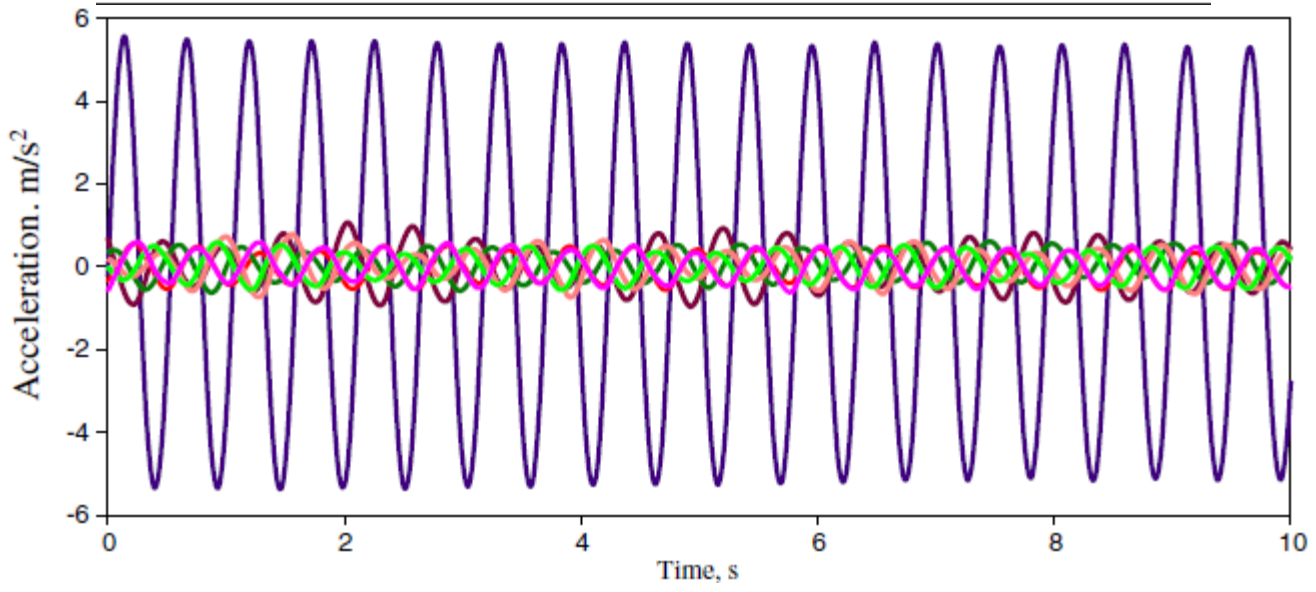
نتایج:



نتایج:

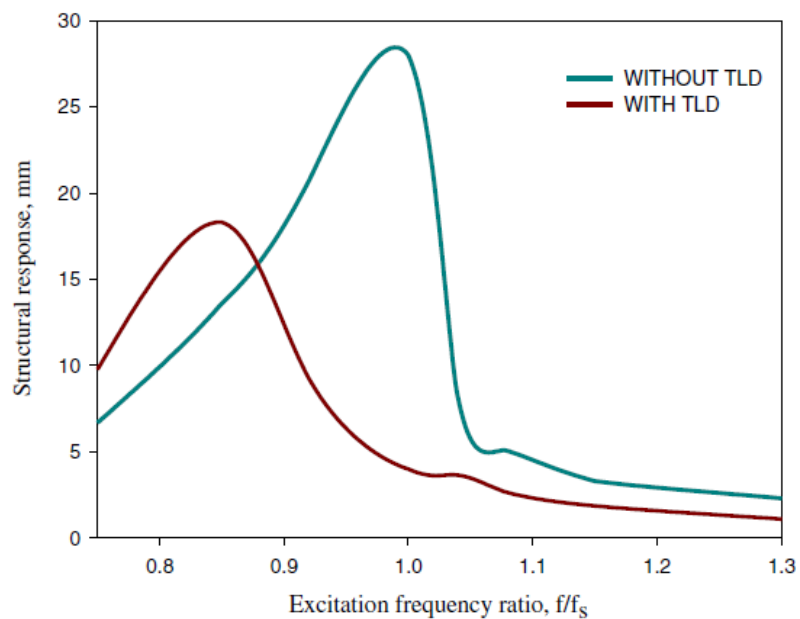
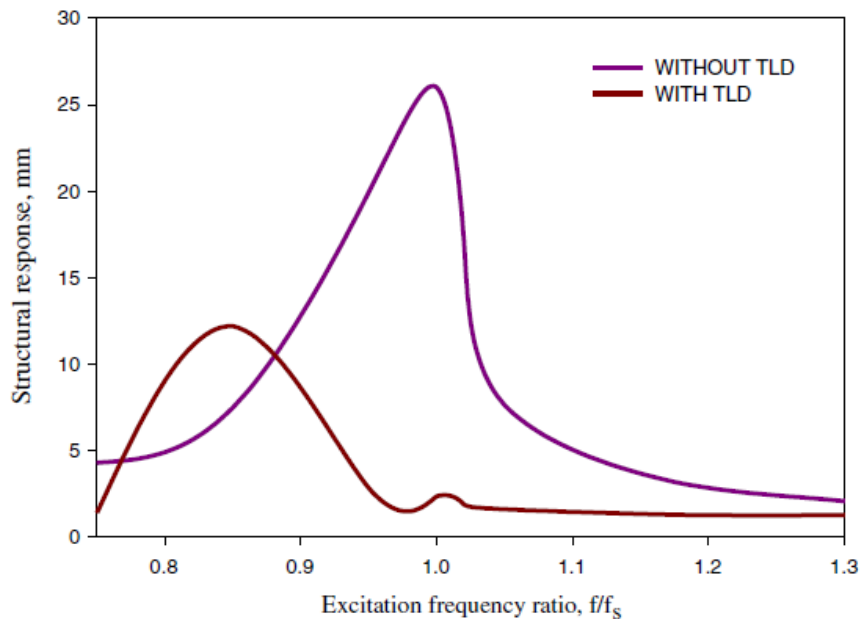


Time histories of structural acceleration with and without TLD (for $TLD_1, \beta = 0.95$).



Time histories of structural acceleration with and without TLD (for $TLD_1, \beta = 1.0$).

نتایج:



کارایی TLD

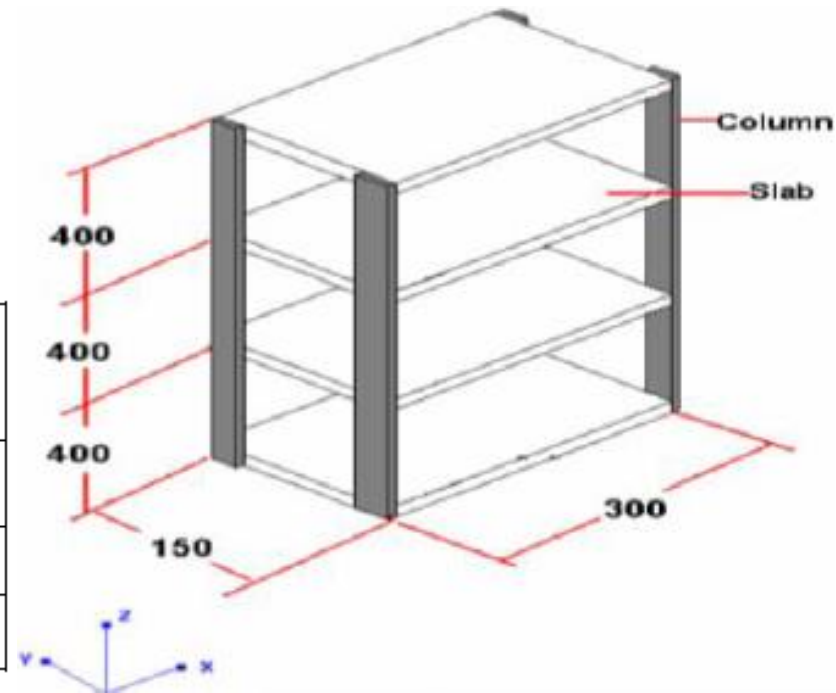


$$\psi = \frac{(x_o - x_{TLD})}{x_{TLD}} \times 100\%$$

Framed Structure with Tuned Liquid Damper Response Behaviour of a Three Storied

Namrata Yannawar, G.R.Patil(2014)

<i>Sr No.</i>	<i>Parts</i>	<i>Dimensions in mm</i>		
		<i>Depth(D)</i>	<i>Width(B)</i>	<i>Length(L)</i>
1	Column	$D_A = 3.00$	$B_A = 25.11$	$L_A = 400.00$
2	Slab	$D_B = 12.70$	$B_B = 150.00$	$L_B = 300.00$



$$f_w = \frac{1}{2\pi} \sqrt{\left[\sqrt{\frac{\pi g}{h}} \tanh\left(\frac{\pi h}{L}\right) \right]}$$

فرکانس TLD

ابعاد مخزن: $96 \times 100 \times 100 \text{ mm}$

g: شتاب ثقل زمین

h: ارتفاع آب

L: طول مخزن در جهت موج

فرکانس تحریک: $2 - 40 \text{ Hz}$

فرکانس طبیعی TLD: 2.84 rad/sec

موقعیت: طبقه سوم

Sr No.	Frequency	Base	First floor	Second floor	Third floor	Sr No.	Frequency	Base	First floor	Second floor	Third floor
1	3.2	3.95	9.16	16.06	24.14	1	2.9	4.19	45.24	80.55	239.55
2	5.2	4	6.74	11	16.48	2	3	4.07	11.94	22.11	68.08

(a)

(b)

Sr No.	Frequency	Base	First floor	Second floor	Third floor
1	4.3	4.05	4.02	3.99	8.31
2	4.4	4.05	4	3.96	7.79

(c)

- (a) Highest Frequency of X-Axis without TLD.
 (b) Highest Frequency of Y-Axis without TLD.
 (c) Highest Frequency of Z-Axis without TLD.
 (d) Highest Frequency of X-Axis with TLD @ Top Floor.
 (e) Highest Frequency of Y-Axis with TLD @ Top Floor.
 (f) Highest Frequency of Z-Axis with TLD @ Top Floor.

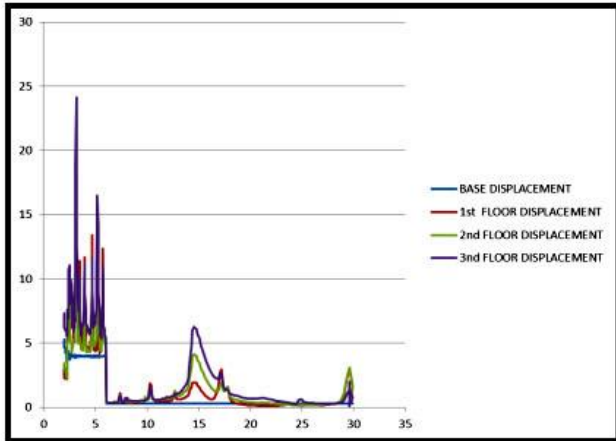
Sr No.	Frequency	Base	First floor	Second floor	Third floor	Sr No.	Frequency	Base	First floor	Second floor	Third floor
1	4.4	6.07	8.33	8.81	19.69	1	2.9	3.89	5.57	10.01	3.7
2	2.9	5.95	6.17	12.5	20.67	2	4	4.03	6.77	9.25	1.69

(d)

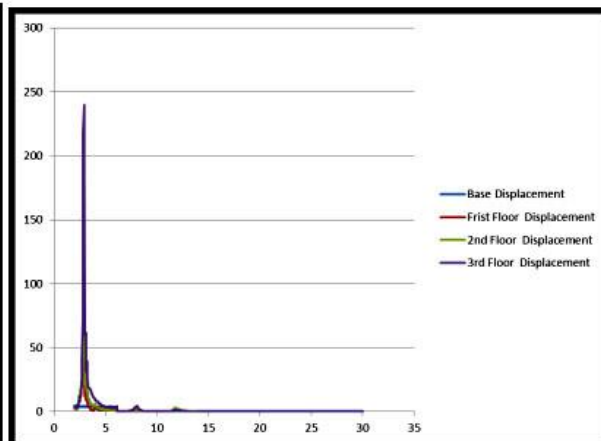
(e)

Sr No.	Frequency	Base	First floor	Second floor	Third floor
1	3.4	3.97	13.74	2.19	3.91
2	2.8	3.88	3.52	3.24	3.91

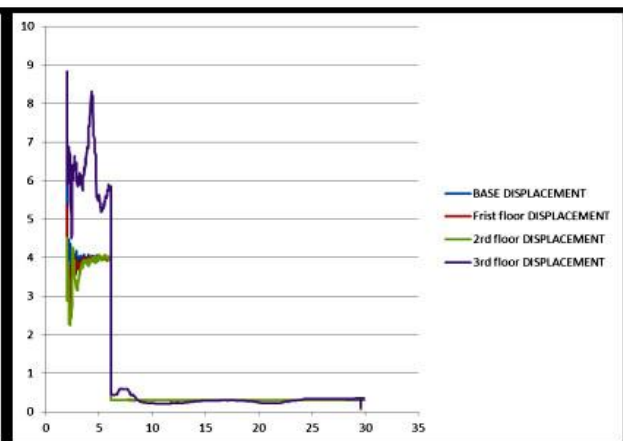
(f)



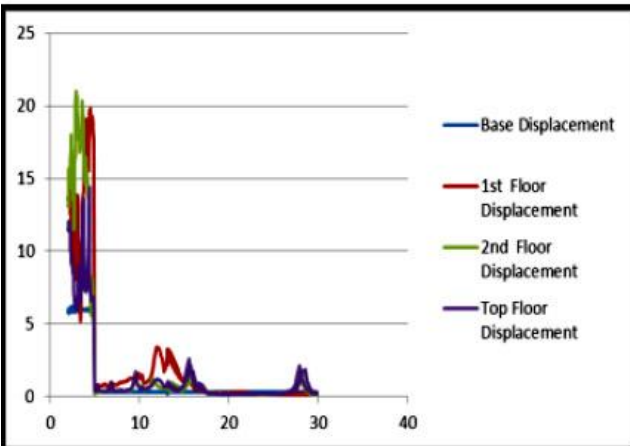
(a)



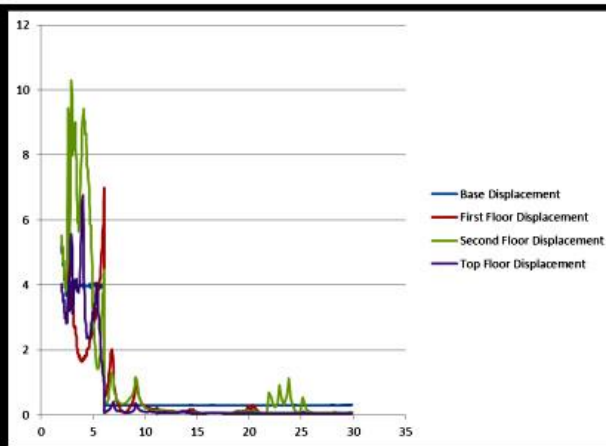
(b)



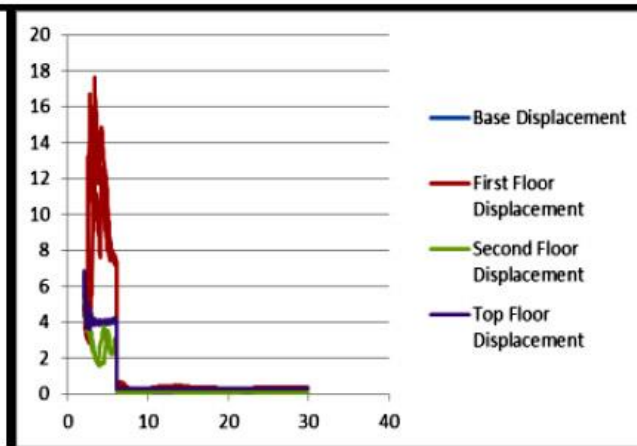
(c)



(d)



(e)



(f)

نتیجه گیری:

تغییر مکان در سه جهت X,Y,Z بسیار بیشتر از حالتی می باشد که مخزن آب مورد استفاده قرار گرفته است.

مخزن آب پر

همانند یک میراگر مایع تنظیمی عمل کرده

باعث کاهش جابجایی طبقات گردیده است

با تشکر از :

رامین گرمرودی

و با سپاس از توجه شما
پایان