LPOB 125 : Systèmes couplés

Niveau L2

Prérequis :

- Mécanique du point et du solide en rotation autour d’un axe fixe (pendule pesant)
- Oscillateurs amortis (masse-ressort avec frottement fluide)

LPOB 125 : Systèmes couplés

Le Taipei 101

- Gratte-ciel d’environ 500m, 700 000 tonnes, 101 étages
- Amortisseur harmonique : Sphère d’acier de 660 tonnes suspendue entre les étages 87 et 92, dissipe les oscillations du bâtiment grâce à des vérins hydrauliques
- Situé à Taiwan : zone soumise à des séismes et des typhons (vents de plus de 200 km/h)

Modes de vibration

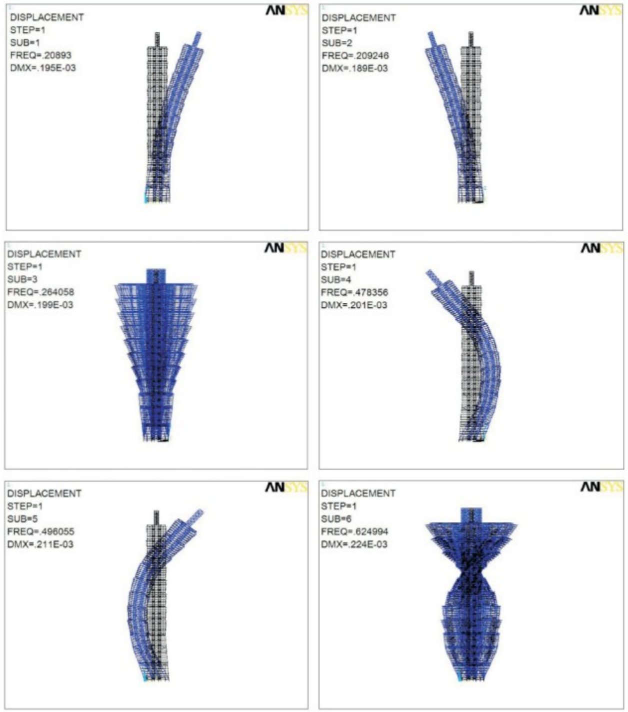


Figure 7. Several mode shapes of Taipei 101 Tower without TMD.

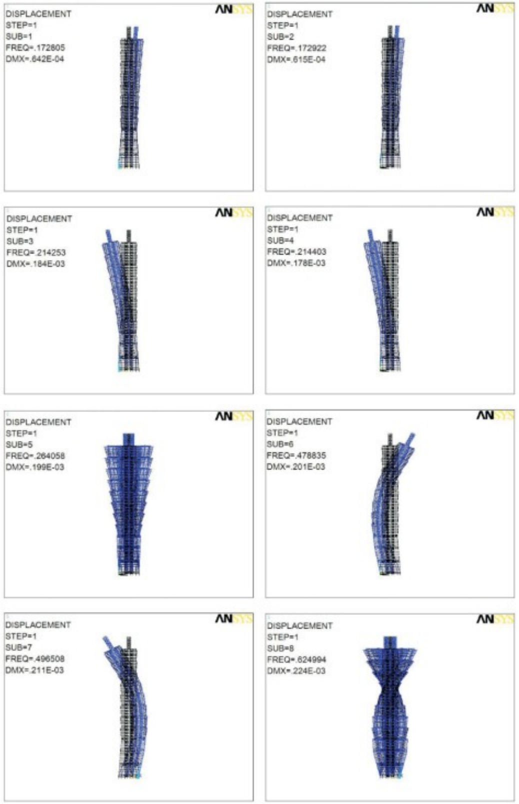


Figure 8. Several mode shapes of Taipei 101 Tower with the TMD.

Amortisseur harmonique : Modèle à 2 masses-ressorts amortis

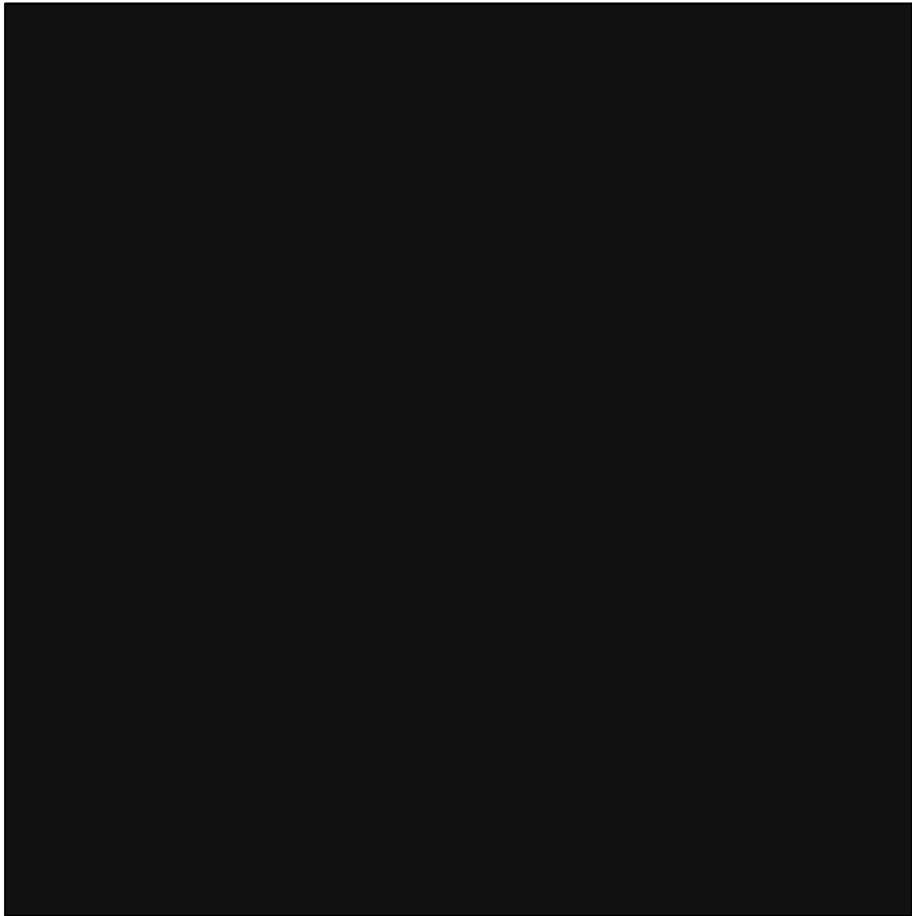
$$x = \frac{(k_a - m_a\omega^2 + i\omega c_a)\,pe^{i\omega t}}{(K_m + k_a - M_m\omega^2 + i\omega c_a)(k_a - m_a\omega^2 + i\omega c_a) - (k_a + i\omega c_a)^2}$$

Adimensionnement :

$$x = \frac{(f^2 - r^2 + 2ir\gamma_a f)}{(\mu f^2 - r^2 + 1 + 2i\mu r\gamma_a f)(f^2 - r^2 + 2ir\gamma_a f) - \mu(f^2 + 2i\gamma_a fr)^2} \cdot \frac{pe^{ir\omega_m t}}{K_m}$$

$$\dot{x} = \frac{(f^2 - r^2 + 2ir\gamma_a f)}{(\mu f^2 - r^2 + 1 + 2i\mu r\gamma_a f)(f^2 - r^2 + 2ir\gamma_a f) - \mu(f^2 + 2ir\gamma_a f)^2} \cdot \frac{pir\omega_m e^{ir\omega_m t}}{K_m}$$

$$\ddot{x} = \frac{(f^2 - r^2 + 2ir\gamma_a f)}{(\mu f^2 - r^2 + 1 + 2i\mu r\gamma_a f)(f^2 - r^2 + 2ir\gamma_a f) - \mu(f^2 + 2ir\gamma_a f)^2} \cdot \frac{-pr^2\omega_m^{\;2} e^{ir\omega_m t}}{K_m}$$



Critère d’optimisation

LEVEL	ACCELERATION (m / sec^2)	EFFECT
1	< 0.05	Humans cannot perceive motion
2	0.05 - 0.1	a) Sensitive people can perceive motion; b) hanging objects may move slightly
3	0.1 - 0.25	a) Majority of people will perceive motion; b) level of motion may affect desk work; c) long - term exposure may produce motion sickness
4	0.25 - 0.4	a) Desk work becomes difficult or almost impossible; b) ambulation still possible
5	0.4 - 0.5	a) People strongly perceive motion; b) difficult to walk naturally; c) standing people may lose balance.
6	0.5 - 0.6	Most people cannot tolerate motion and are unable to walk naturally
7	0.6 - 0.7	People cannot walk or tolerate motion.
8	> 0.85	Objects begin to fall and people may be injured

Table 2: Human Perception levels [35]

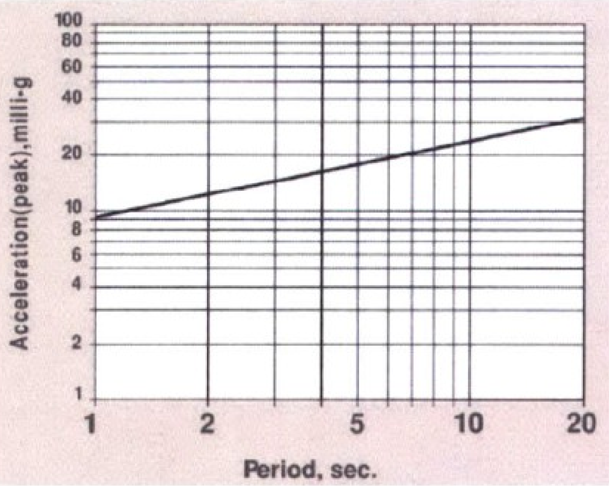


Table 3: ISO Guideline for 5 Year Acceleration in Buildings

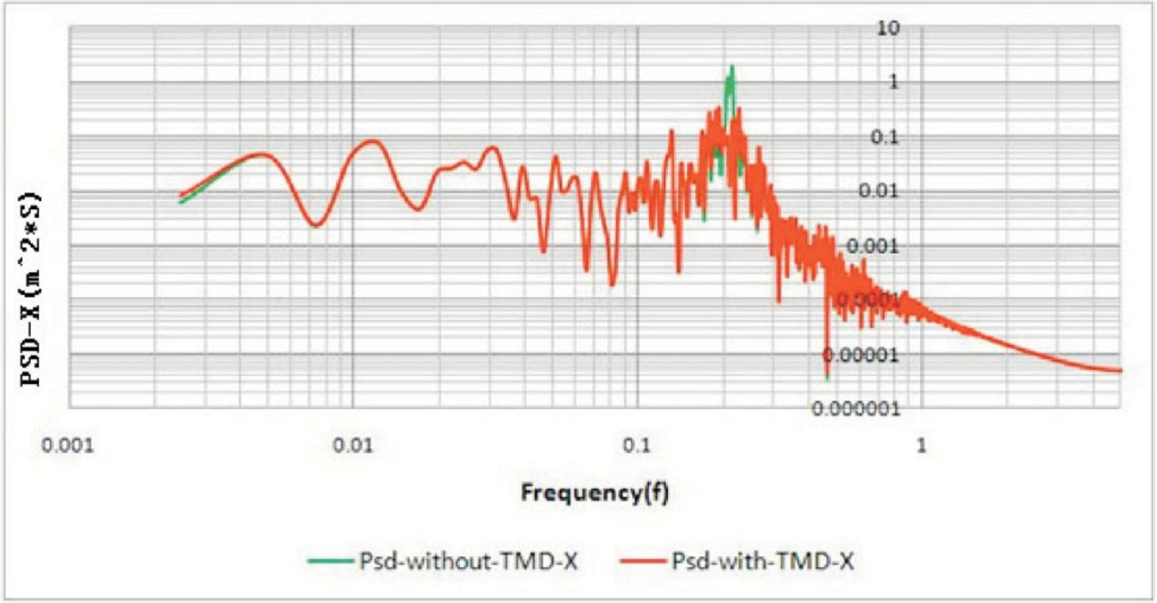
Source : Structural Systems and Tuned Mass Dampers of Super-Tall Buildings, Ioannis Kourakis

Table 1. The optimal parameters for a TMD attached to a SDOF system

Minimizing items	$f_{(opt)}^{\ 2}$	$\gamma_{a(opt)}^{\ 2}$
X	$\frac{1}{(1+\mu)^2}$	$\frac{3\mu}{8(1+\mu)^3}$
$\dot{X}$	$\frac{1+0.5\mu}{(1+\mu)^2}$	$\frac{\mu(3+3\mu+0.625\mu^2)}{4(2+\mu)(1+\mu)^3}$
$\ddot{X}$	$\frac{1}{(1+\mu)}$	$\frac{3\mu}{4(2+\mu)(1+\mu)}$

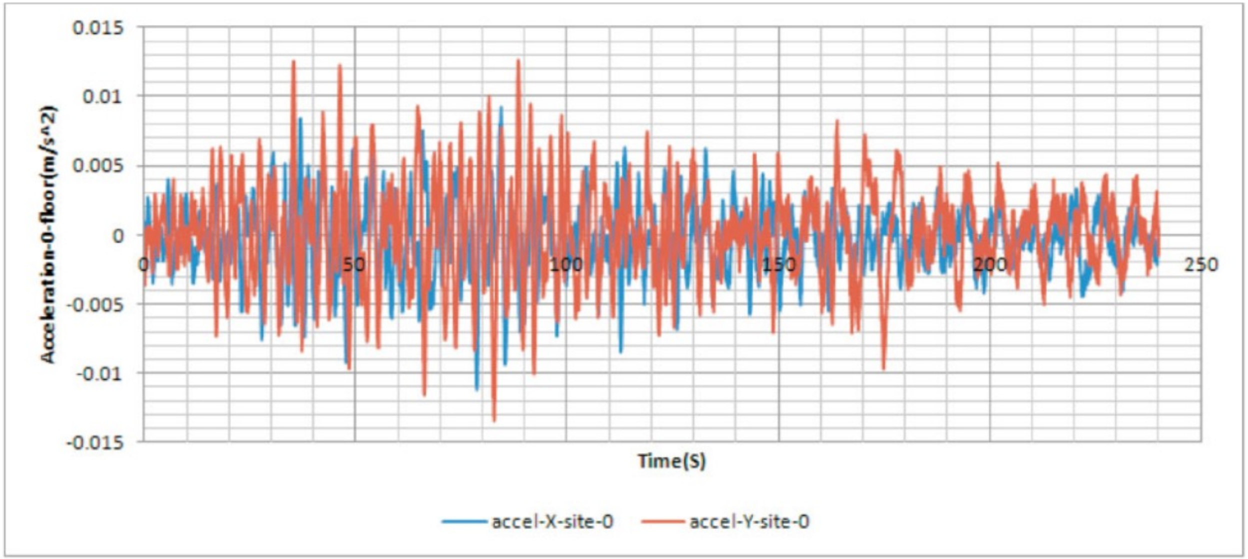
Source : Vibration Control in a 101-Storey Building Using a Tuned Mass Damper, Alex Y. Tuan , G. Q. Shang

Diagramme de Bode dans la littérature



Source : Vibration Control in a 101-Storey Building Using a Tuned Mass Damper, Alex Y. Tuan , G. Q. Shang

Efficacité de l'amortisseur harmonique : Réponse au séisme de Sichuan en 2008



Accélération mesurée au pied du bâtiment pendant le séisme

Table 8. The accelerations on the uppermost residential floor, when it is subjected to remote earthquake excitation

Accelerations of the 88th floor (m^2/s)	$a_{X\,max}$	$a_{Y\,max}$	a_{max}
Without-TMD	0.066	0.109	0.102

Accélération maximale estimée en haut du bâtiment, en absence d'amortisseur harmonique (TMD)

Source : Vibration Control in a 101-Storey Building Using a Tuned Mass Damper, Alex Y. Tuan , G. Q. Shang

Modèles à N masses-ressorts

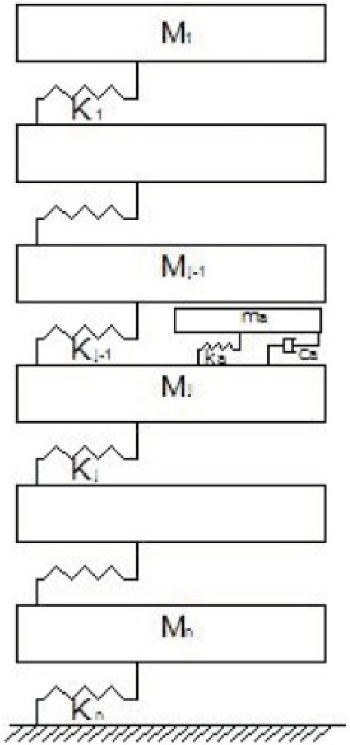


Figure 2. A MDOF-TMD system.

Source : Vibration Control in a 101-Storey Building Using a Tuned Mass Damper, Alex Y. Tuan , G. Q. Shang

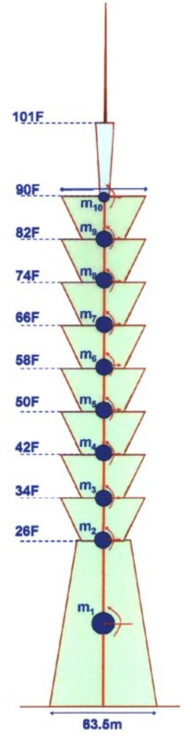


Figure 50: Equivalent 10-DOF

Source : Structural Systems and Tuned Mass Dampers of Super-Tall Buildings, Ioannis Kourakis