”GHEORGHE ASACHI” TECHNICAL UNIVERSITY OF IAȘI
Faculty of Civil Engineering and Building Services
Civil Engineering – Bachelor Program, English teaching, first year

LABORATORY WORK 1
Word/Text Processors (Word 2007)

Practice test

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TEST at *Use of Computers* for Civil Engineering Students

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3.1 EQUATIONS OF MOTION

In Figure 3.1, a *n*-degree of freedom lumped masses model is shown. This stick model is a very simplified one, corresponding to a plane structure. However, from academic point of view, using this model is a good approach for understanding the complexity of phenomena that take place.

The dynamic second degree differential matrix equation of motion for a MDOFS, like that in Figure 3.1, submitted to the seismic load can be similarly deduced as in the case of SDOFS

$$\mathbf{m}\ddot{\mathbf{u}}_{abs}(t) + \mathbf{c}\dot{\mathbf{u}}(t) + \mathbf{k}\mathbf{u}(t) = \mathbf{0} \qquad (3.1)$$

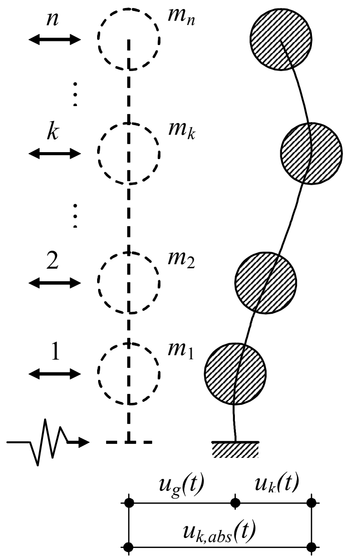

Figure 3.1 Multi-degree of freedom system

where **m** (usually a diagonal matrix) is the mass matrix, **c** is the damping matrix, and **k** is the stiffness matrix. $\mathbf{u}(t)$ is the vector of displacements relative to the base of the structure and $\mathbf{u}_{abs}(t)$ is the vector of absolute displacements. At the right of the Equation (3.1), **0**, means a column vector with all *n* elements zero.

3.2 MODAL SUPERPOSITION APPROACH

Replacing $\overline{m}_r = \sum_{i=1}^{n} m_i U_{ir}^2$ in (3.13), the next equation is obtained

$$\ddot{\varphi}_r(t) + 2\xi_r\omega_r\dot{\varphi}_r(t) + \omega_r^2\varphi_r(t) = -\frac{\sum_{i=1}^{n} m_i U_{ir}}{\sum_{i=1}^{n} m_i U_{ir}^2}\ddot{u}_g(t) \qquad (3.14)$$

which is similar with a one degree of freedom dynamic equation of motion. The solution for (3.14) is

$$\varphi_r(t) = -\frac{1}{\omega_r}\frac{\sum_{i=1}^{n} m_i U_{ir}}{\sum_{i=1}^{n} m_i U_{ir}^2}\int_0^t \ddot{u}_g(\tau)e^{-\xi_r\omega_r(t-\tau)}\sin\omega_{D,r}(t-\tau)d\tau \qquad (3.15)$$

Now, recalling the Equation (3.9), the response on the *k*-th degree of freedom may be rewritten as follows

$$u_k(t) = \sum_{r=1}^{n} u_{kr}(t) = \sum_{r=1}^{n} U_{kr}\varphi_r(t) \tag{3.16}$$

where $u_{kr}(t) = U_{kr}\varphi_r(t)$ can be seen as the contribution of the r-th mode of vibration to the response on the k-th degree of freedom. Using the Equation (3.15), each element of the sum in (3.16) becomes

$$u_{kr}(t) = -\frac{1}{\omega_r} U_{kr} \frac{\sum_{i=1}^{n} m_i U_{ir}}{\sum_{i=1}^{n} m_i U_{ir}^2} \int_0^t \ddot{u}_g(\tau) e^{-\xi_r \omega_r (t-\tau)} \sin \omega_{D,r}(t-\tau) d\tau \tag{3.17}$$

or, introducing the corresponding distribution coefficient, η_{kr}, where

$$\eta_{kr} = U_{kr} \frac{\sum_{i=1}^{n} m_i U_{ir}}{\sum_{i=1}^{n} m_i U_{ir}^2} \tag{3.18}$$

the Equation (3.17) is transformed into the next one

$$u_{kr}(t) = -\frac{1}{\omega_r} \eta_{kr} \int_0^t \ddot{u}_g(\tau) e^{-\xi_r \omega_r (t-\tau)} \sin \omega_{D,r}(t-\tau) d\tau \tag{3.19}$$

5.4 ACTIVE CONTROL. THEORETICAL ASPECTS

Every construction suffers changes during its life. At the same time, the environment where the structure is placed is changing, too. Therefore one could compare existing constructions to living beings. However, the most common way a civil engineering structure overcomes external loads is to *resist* to them. The living beings not only resist but also *adapt* to the environmental aggressiveness, responding in a different manner to different actions or intensities.

Adapting to external loads and to structural changes is a basic idea in active structural control. Criteria and some results are shown in the Table 1.

Table 1. Comparisons of results for some criteria

Criteria	No Cntrl.	El Centro Earthquake		Mexico Earthquake	
		Centralized	Overlapping	Centralized	Overlapping
J_1	1.0000	0.3868	0.4134	0.4582	0.5343
J_2	1.0000	1.0681	1.2626	1.3693	1.5838
J_3	1.0000	0.2944	0.3147	0.5836	0.6878
J_4	1.0000	0.6252	0.6480	0.6140	0.6718
J_5	0.8029 0.1481 0.3832	0.1861 - -	0.2090 - -	- 0.0775 -	- 0.0904 -
J_6	1.0000	1.2006	1.2498	2.3317	2.0998
J_7	1.0000	0.2257	0.2601	0.3983	0.4715

In 1972, Prof. James T.P. Yao, through his paper "Concept of Structural Control", is defining the start for this new branch in structural synthesis. Figure 5.5 shows a feedback system as J.P.Yao viewed it. The author describes a structural controlled structure as an error-activated structural system the behavior which varies automatically in accordance with unpredictable variations in the loading as well as environmental conditions and thereby produces desirable responses under all possible loading conditions.

From the point of view of theoretical studies and application methodologies, there are two main approaches in structural control:

i. *LQG* (*Linear Quadratic Gain*) control, based on time domain

ii. H^{∞} and *μ-Synthesis* control, based on frequency domain.

These two ways are very developed in many sub-methods and versions. Meanwhile, additional tools are added to the main methods: *fuzzy sets analysis* and *neuronal networks*.

From the first category of control, *LQG*, very popular are: pole assignment, optimal control, instantaneous optimal control, modal control, critical modal control, and sliding modes control method.

Majority of these methods is based on rewriting the structural dynamics classical and familiar system of equations

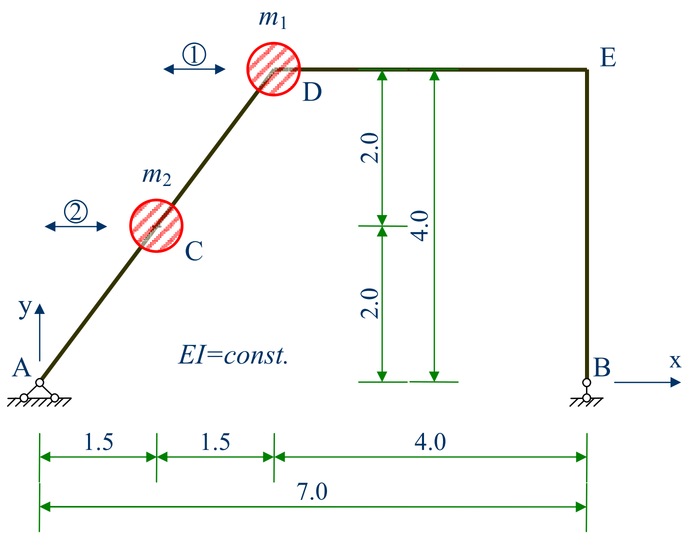

Figure 5.5 Dynamic System

$$\mathbf{M}_s\ddot{\mathbf{z}} + \mathbf{C}_s\dot{\mathbf{z}} + \mathbf{K}_s\mathbf{z} = \mathbf{f} \tag{5.2}$$

in the form of state equation

$$\begin{cases} \dot{\mathbf{x}} = \mathbf{A}\mathbf{x} + \mathbf{B}\mathbf{f} \\ \mathbf{y} = \mathbf{C}\mathbf{x} + \mathbf{D}\mathbf{f} \end{cases} \tag{5.3}$$

In the Equation (5.2), $\mathbf{M}_s$, $\mathbf{C}_s$, and $\mathbf{K}_s$ are the mass, damping, and stiffness matrices of the structure; **z** is the vector of the generalized displacement vector, and **f** is the vector of the external forces.

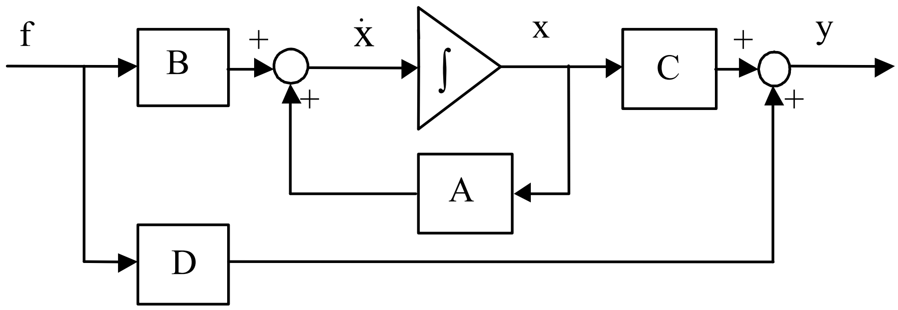

Figure 5.6 System described by Equation (5.3)

In the Equation (5.3), **A** is the system matrix, **B** is the load location matrix, **C** is the measurement matrix, and **D** is a matrix showing the influence of the input, **f**, to the output, **y**. Equation (5.3) is described by Figure 5.6.

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