Passive Structural Control (HW-5)

Due: 5/9

1. **Find the key parameters**

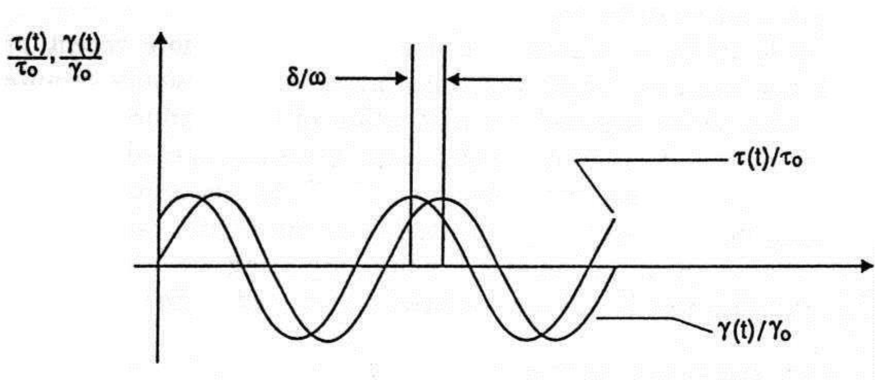
Two sets of VE material had been tested in NCREE and the data are as attached (Excel file: VE damper properties test). You are required to find the G'' 、G' 、η, and write the descriptions on how to get them.

Area of VE is assumed as 15000cm^2

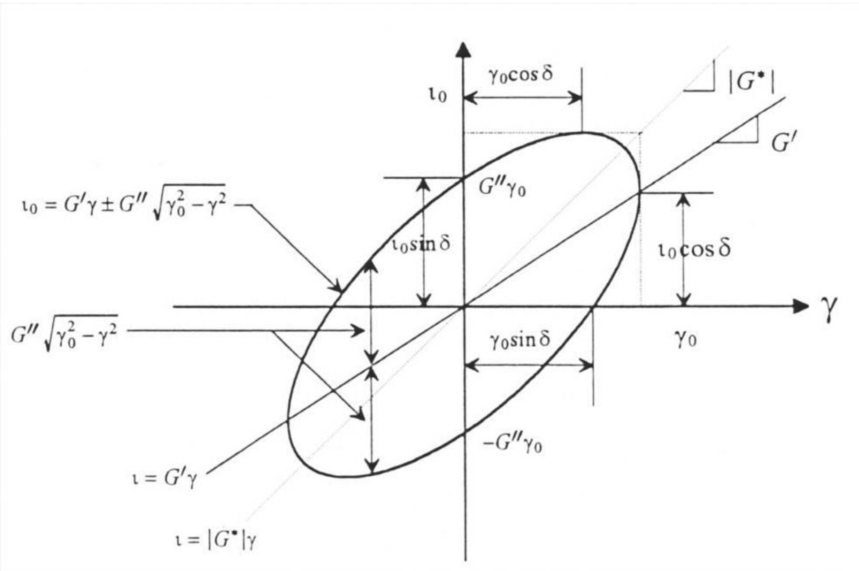
Thickness of VE is assumed as 5 mm

For each data set you are required to use two methods:

a. Using the time-history of stress and strain



b. Using the stress-strain curve



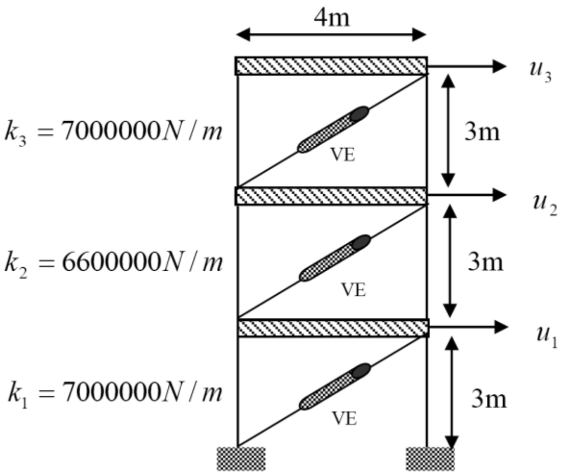
2. **Modal Strain Energy Method:**

Consider a three story shear frame as follow. The floors are assumed to be rigid. And the columns are assumed to be massless. The mass of each floor is 10 ton. Note that we install VE damper every story as the figure says. Viscoelastic damper with the following properties:

- Two pieces of VE material per damper, damper thickness= 2.4 cm, damper area = 9 cm x 11 cm.
- The storage modulus and loss factor can be obtained by

  $G' = e^{10.17433} \times T^{-3.10205} \times 1.34840758 \ \ (MPa)$

  $\eta_v = 1.2 \quad ; \quad T = 32^{\circ} \ \ \mathrm{C}$



Assume that the brace is much more stiffness than that of the damper, determine:

(1) The stiffness matrix of the frame after dampers is installed.

(2) Assume that the first mode shape is $\begin{bmatrix} 0.4451 \\ 0.8019 \\ 1 \end{bmatrix}$, please find the damping ratio which is contributed by the VE dampers according to **full matrix method in modal strain energy method**.

(3) Assume that the first mode shape is $\begin{bmatrix} 0.4451 \\ 0.8019 \\ 1 \end{bmatrix}$, please find the damping

ratio which is contributed by the VE dampers according to **frequency shift method in modal strain energy method**.

3. **Design VE Damper**

Please devise viscoelastic (VE) dampers with 20% damping ratio (2% inherent damping of the steel frame + 18% VE dampers provided) for design the structure which you built in HW#1.

(1) The properties of VE dampers as follows:

A. Elastic stiffness:

$$K_d = 8.57 \times f_1^{0.3} \times \gamma^{-0.24} \times e^{-0.073T} \times 10^{-3} \times \left(\frac{A}{t}\right) {}^{tf}/_{cm}$$

B. Damping coefficient:

$$C_d = 2.18 \times f_1^{-0.53} \times \gamma^{-0.089} \times e^{-0.1T} \times 10^{-3} \times \left(\frac{A}{t}\right) {}^{tf}/_{cm}$$

C. Loss factor

$$\eta_v = 2\pi \times f_1 \times \left(\frac{C_d}{K_d}\right)$$

Where

f_1: Natural frequency of the bare frame

T: Temperature. Assume T=20℃

γ: Shear strain. ($\gamma_{max} = 300\%$)

A: Shear area of the damper (cm^2)

t: Thickness of the damper (cm)

(2) Describe design procedures and fill out the following tables

Thickness of the damper (mm)	_________ mm
Shear area of the damper (m^2)	_________ m^2

Period(sec)	1^{st} mode	2^{nd} mode	3^{rd} mode
Bare frame	____	____	____
Bare frame with VE dampers	____	____	____

(3) Scale time history records El Centro and TCU068 (attached) to PGA=0.32g and use it for time history analysis. Plot the time history of the displacement and acceleration at roof for structure with and without damper.

(4) Fill out your modeling output data as following table (absolute maximum). Compare the absolute maximum of floor displacement and story drift for comparison and make discussion on the result.

<table>
<tr><td colspan="10">Name of Ground Motion</td></tr>
<tr><td rowspan="4">Floor</td><td colspan="3">Bare frame</td><td colspan="3">Bare frame +VE</td><td colspan="3">Ratio of Responses</td></tr>
<tr><td>(1)</td><td>(2)</td><td>(3)</td><td>(4)</td><td>(5)</td><td>(6)</td><td>(4)/(1)</td><td>(5)/(2)</td><td>(6)/(3)</td></tr>
<tr><td>Dis.</td><td>Vel.</td><td>Acc.</td><td>Dis.</td><td>Vel.</td><td>Acc.</td><td rowspan="2">Dis.
Ratio</td><td rowspan="2">Vel.
Ratio</td><td rowspan="2">Acc.
Ratio</td></tr>
<tr><td>cm</td><td>cm/s</td><td>gal</td><td>cm</td><td>cm/s</td><td>gal</td></tr>
<tr><td>3</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

4. **Design VE Damper**

According to the point view of first mode of Problem 3, please plot the T_e/T_0 (vertical) to SR_{VE} (horizontal) diagram and ξ_{VE} to SR_{VE} diagram. Assume the structure remains in elastic.