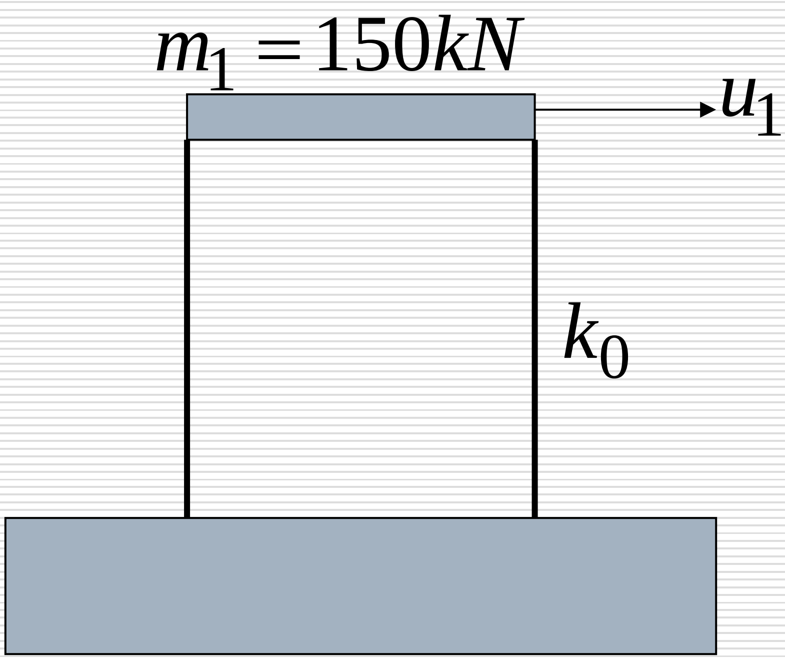
Assignment 3 (June 11, submit by June 25)

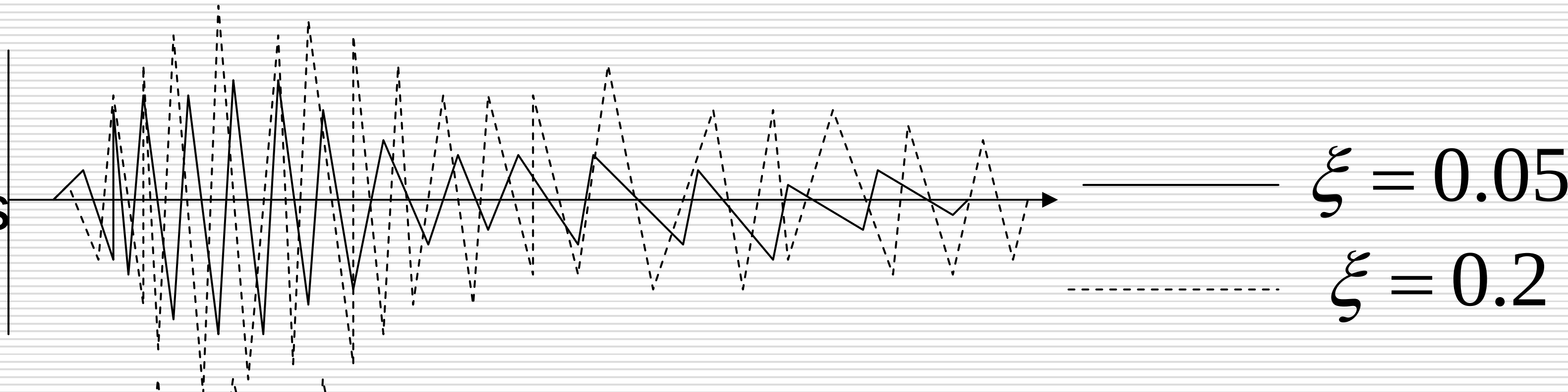
Compute response accelerations and displacements of a SDOF system shown. The spring stiffness should be set so that the natural period of the system is 0.5s, 0.75s, 1s, 1.25s. 1.5s and 2s. Assume that the damping ratio is 0.05 and 0.2.



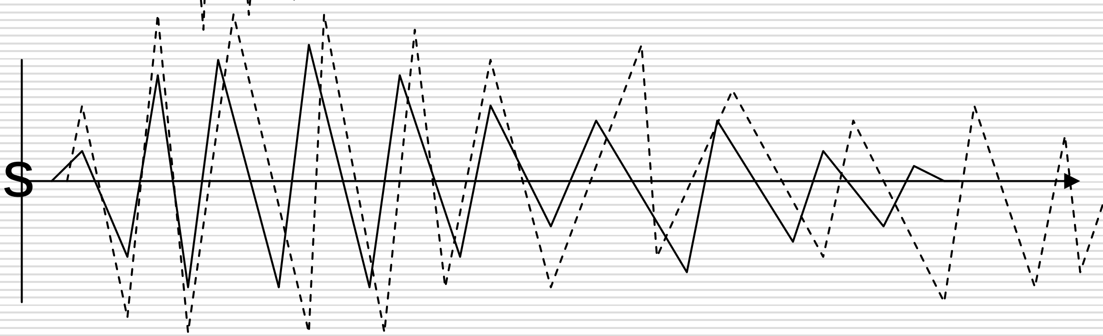
$$T = 2\pi\sqrt{\frac{m}{k_0}}$$

1) Plot the relative displacement and absolute acceleration shown below for each of the two damping ratios.

T=0.5s

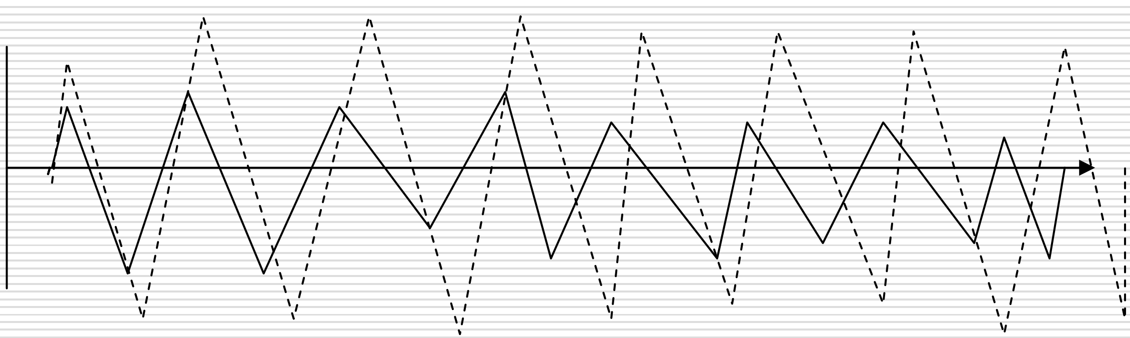


T=0.75s



T=1s, 1.25s, 1.5s

T=2s



2) Plot the peak absolute acceleration and the peak relative displacement as shown below

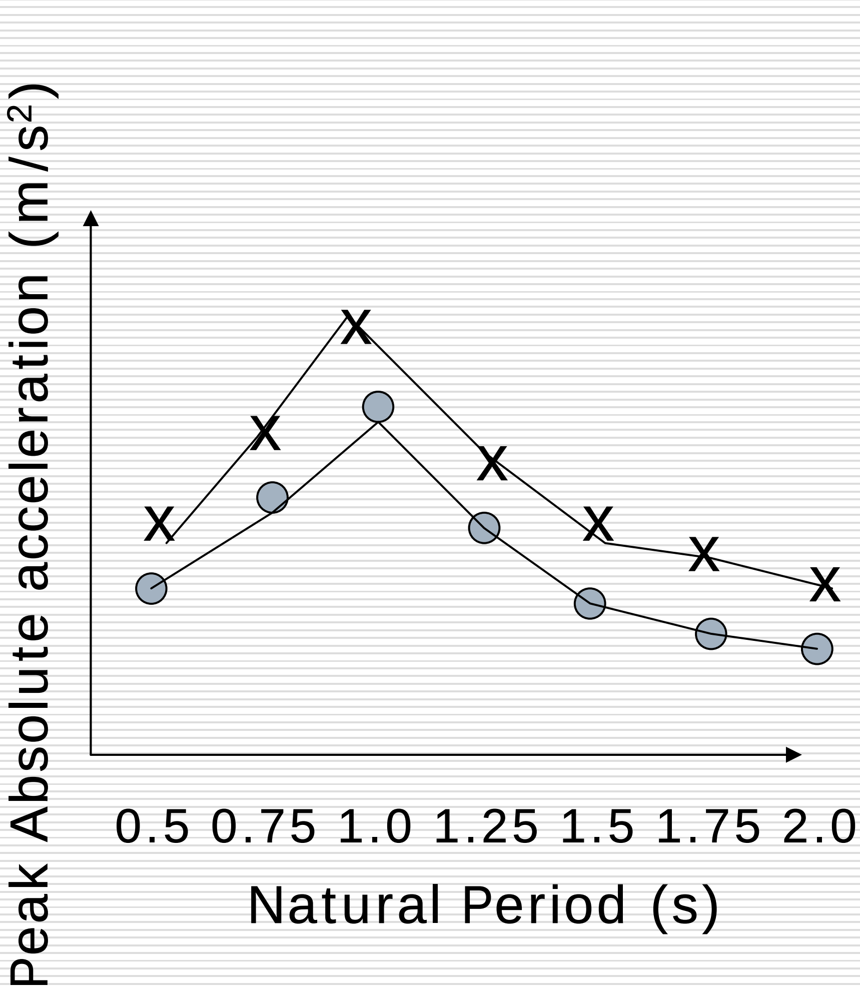


Fig. 2 Response acceleration spectrum

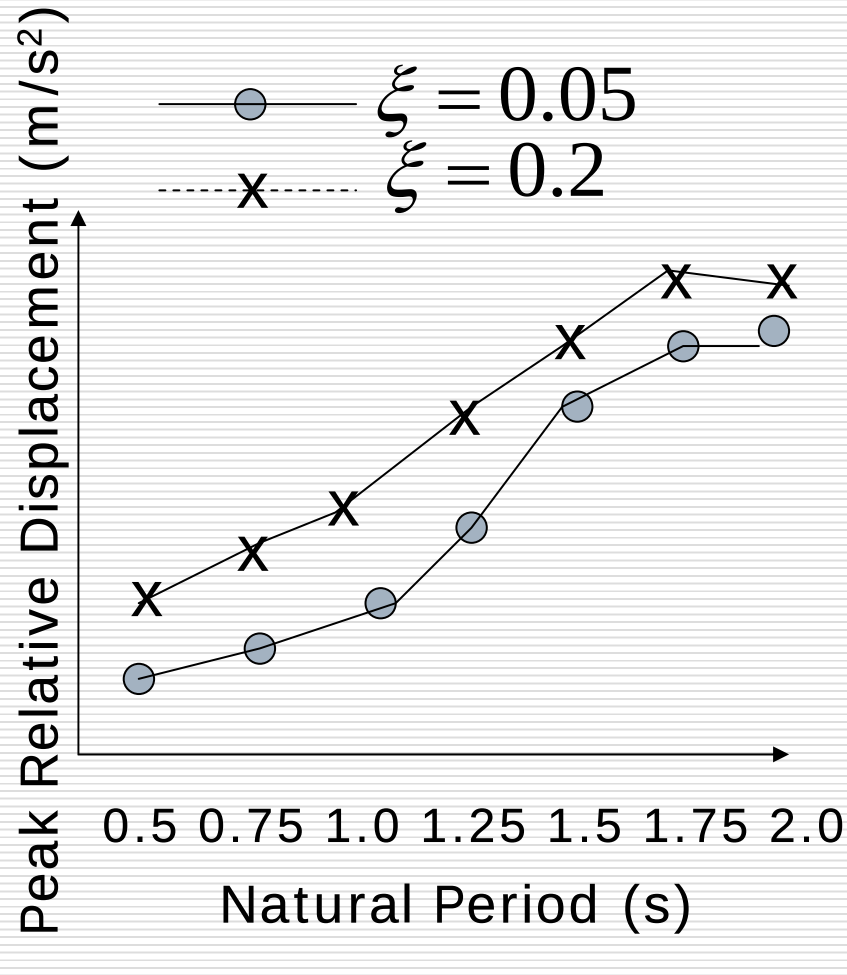
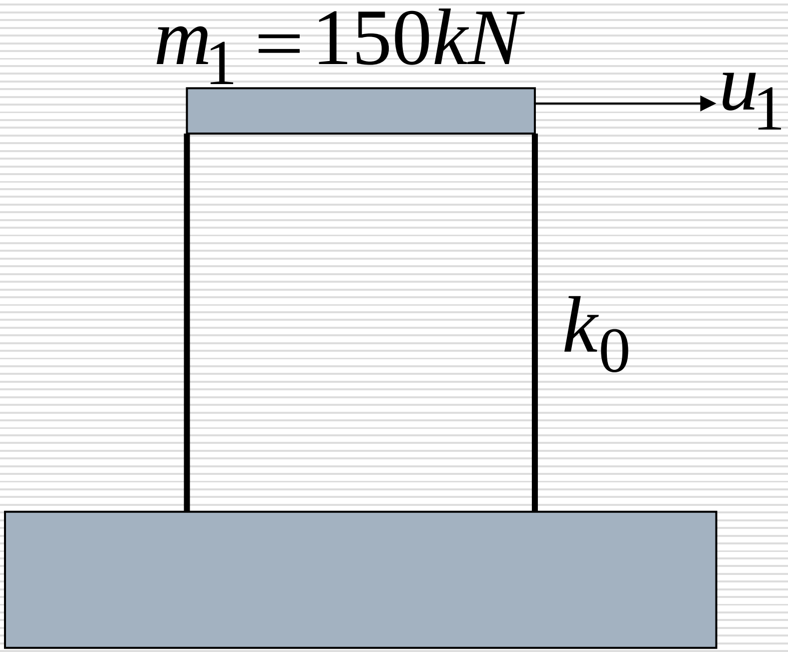


Fig. 3 Response displacement spectrum

Assignment 4 (June 11, submit by June 25)

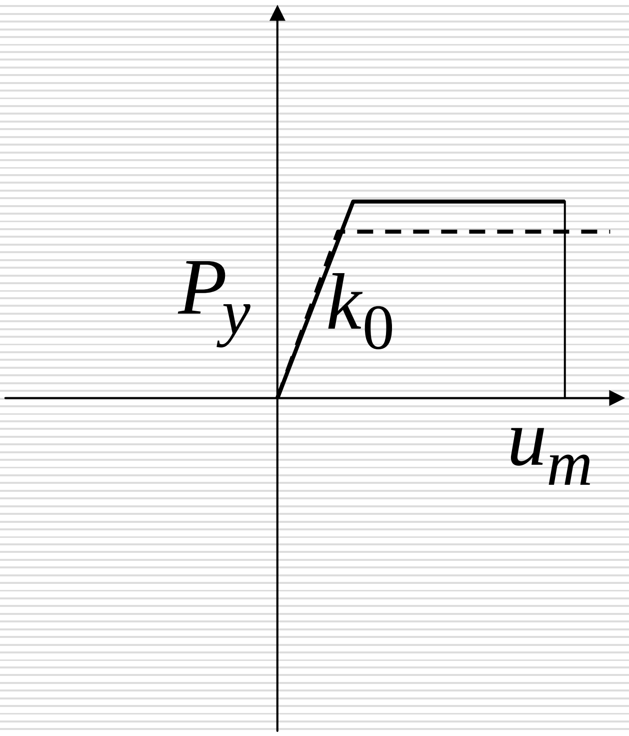
Compute the force reduction factor for the JMA Kobe ground acceleration (1995 Kobe earthquake) at the the target displacement ductility factor $\mu_T = 4$. For this purpose, assume a linear and bilinear (elasto-plastic) SDOF system with the damping ratio of 0.05 shown.



$$T = 2\pi\sqrt{\frac{m}{k_0}}$$

1) Compute the initial spring stiffness k_0 so that the natural period of the system T becomes 0.5s, and 1s.
2) Determine the yield strength P_y so that the response ductility capacity is nearly 4 (4+/-0.1 based on iteration*.
3) For computing the linear response, assume that P_y is sufficiently large so that the system stays in the elastic range.
4) Plot the response accelerations (Absolute accelerations) and response displacements (relative displacements).
5) Evaluate the force reduction factor for T=0.5 s and T=1s.
6) Evaluate the applicability of the equal displacement and equal energy assumptions.
7) Evaluate the residual displacement.

*Iteration



1) Assume P_y^1 appropriately, and compute the peak response displacement u_m^1
2) Evaluate the response displacement ductility factor μ^1 as

$$\mu^1 \equiv u_m{}^1 / u_y$$

3) If $\mu_1 > \mu_T$, increase P_y, and if $\mu_1 < \mu_T$, decrease P_y, and compute u_m^2 and μ_2.
4) If μ_2 is with +/-0.1 from the target ductility factor μ_T, stop. Otherwise, continue the process of 2) and 3) until the convergence is achieved.

Plot the response displacements and accelerations

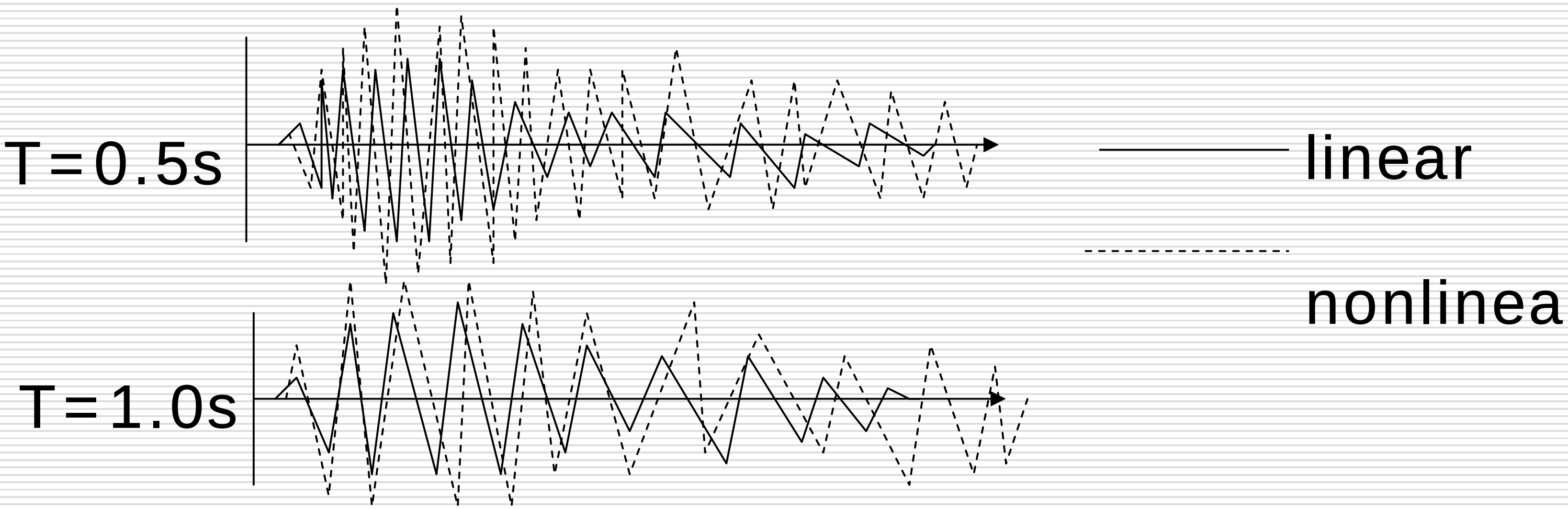


Fig. 1 Absolute acceleration responses

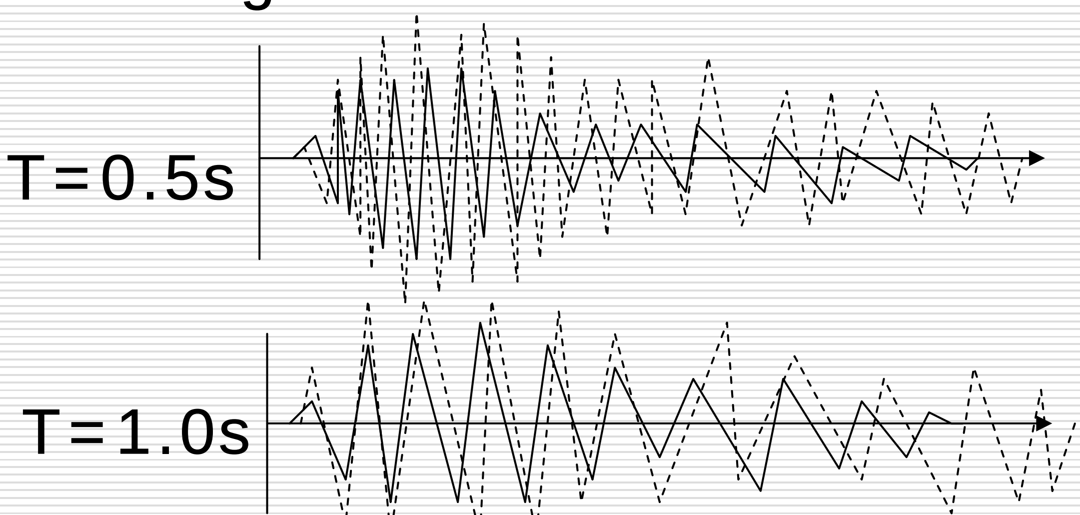


Fig. 2 Relative displacement responses

Evaluate the force reduction R factor as

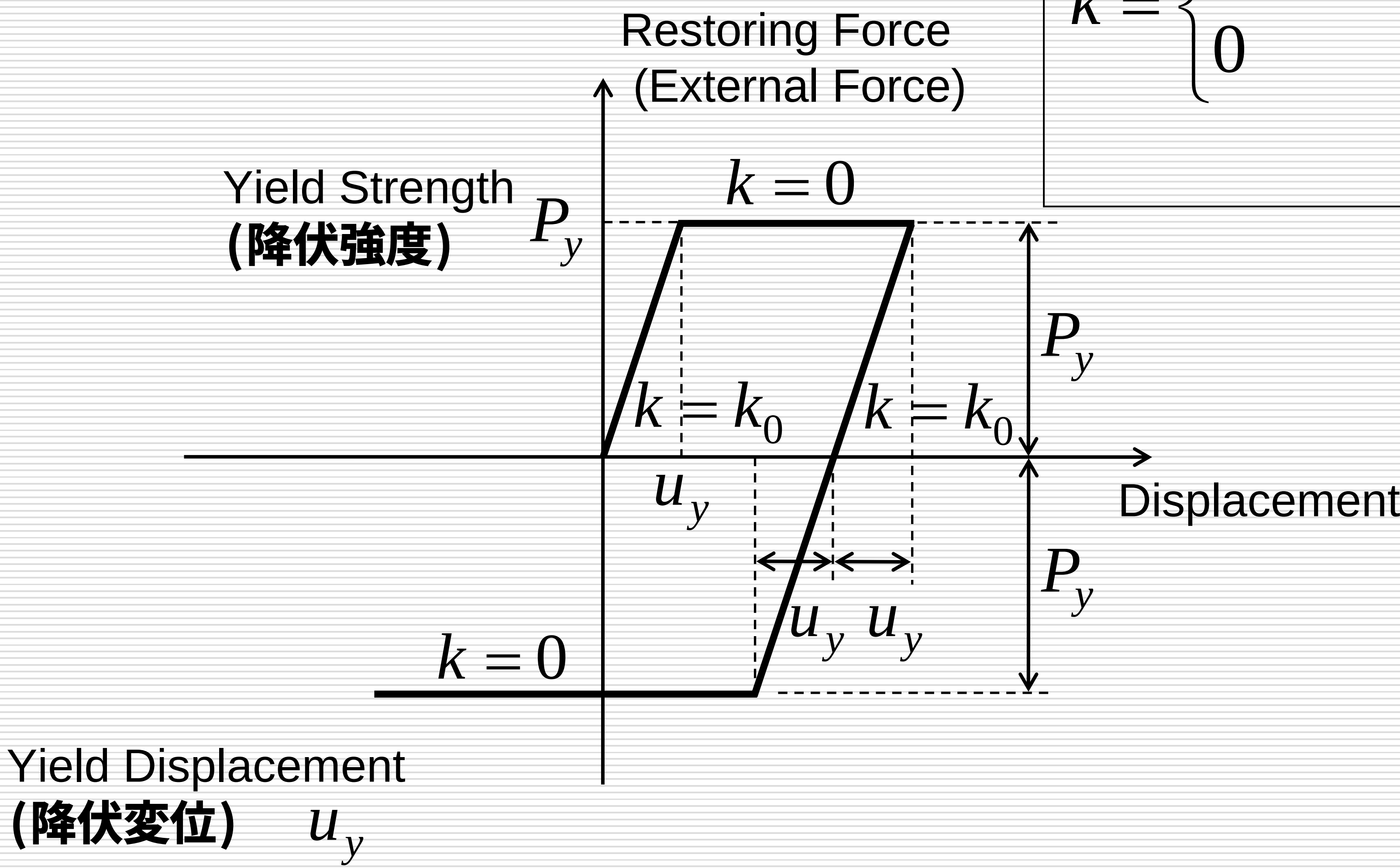
$$R \equiv \frac{\mathrm{Re}\,stroring\ \ force}{P_y}$$

- Restoring force of the elastic system is shown in the Excel at the right most line.
- P_y is the assumed yield strength of the SDOF system in the nonlinear analysis

Elasto-plastic Hysteresis (弾塑性履歴特性)

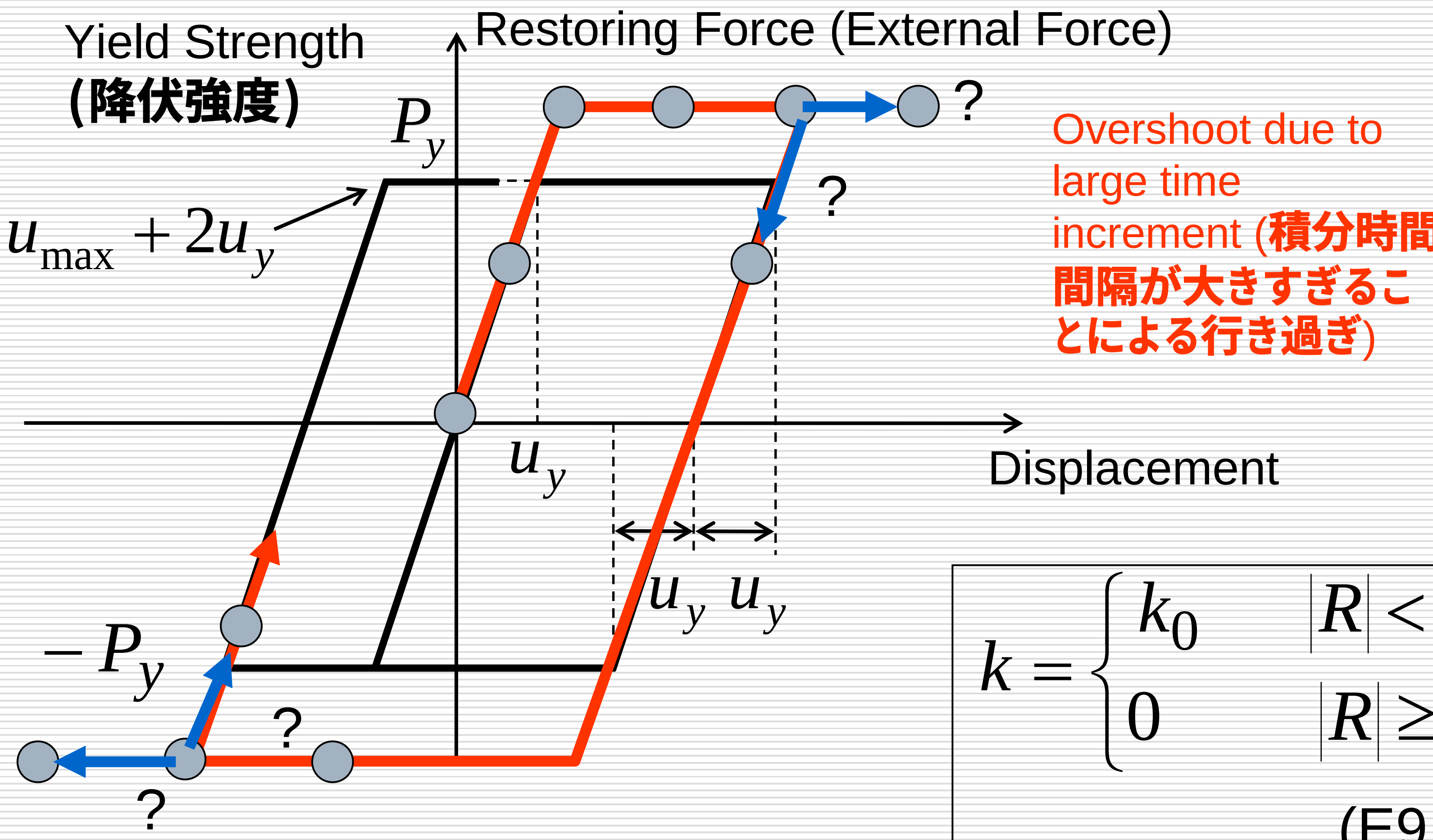
●Hysteresis of elasto-plastic system is generally represented as shown below.

$$k = \begin{cases} k_0 & |R| < P_y \\ 0 & |R| \geq P_y \end{cases} \quad \text{(E9.1)}$$



● In the numerical analysis, change of stiffness from the elastic stage to plastic stage can be controlled by Eq. (E9.1)

● However Eq. (E9.1) cannot control whether unloading occurs or not.

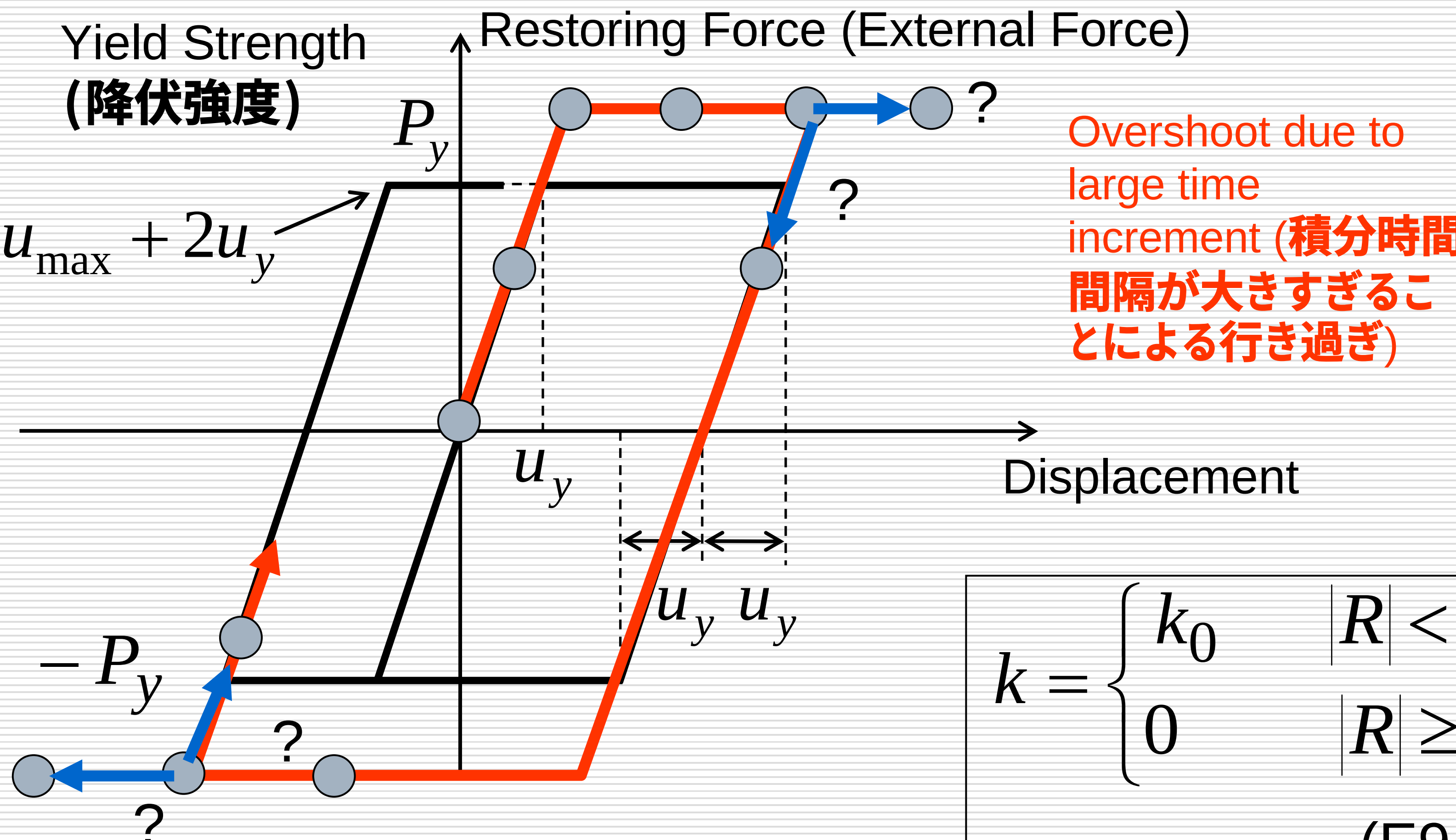


$$k = \begin{cases} k_0 & |R| < P_y \\ 0 & |R| \geq P_y \end{cases}$$

(E9.1)

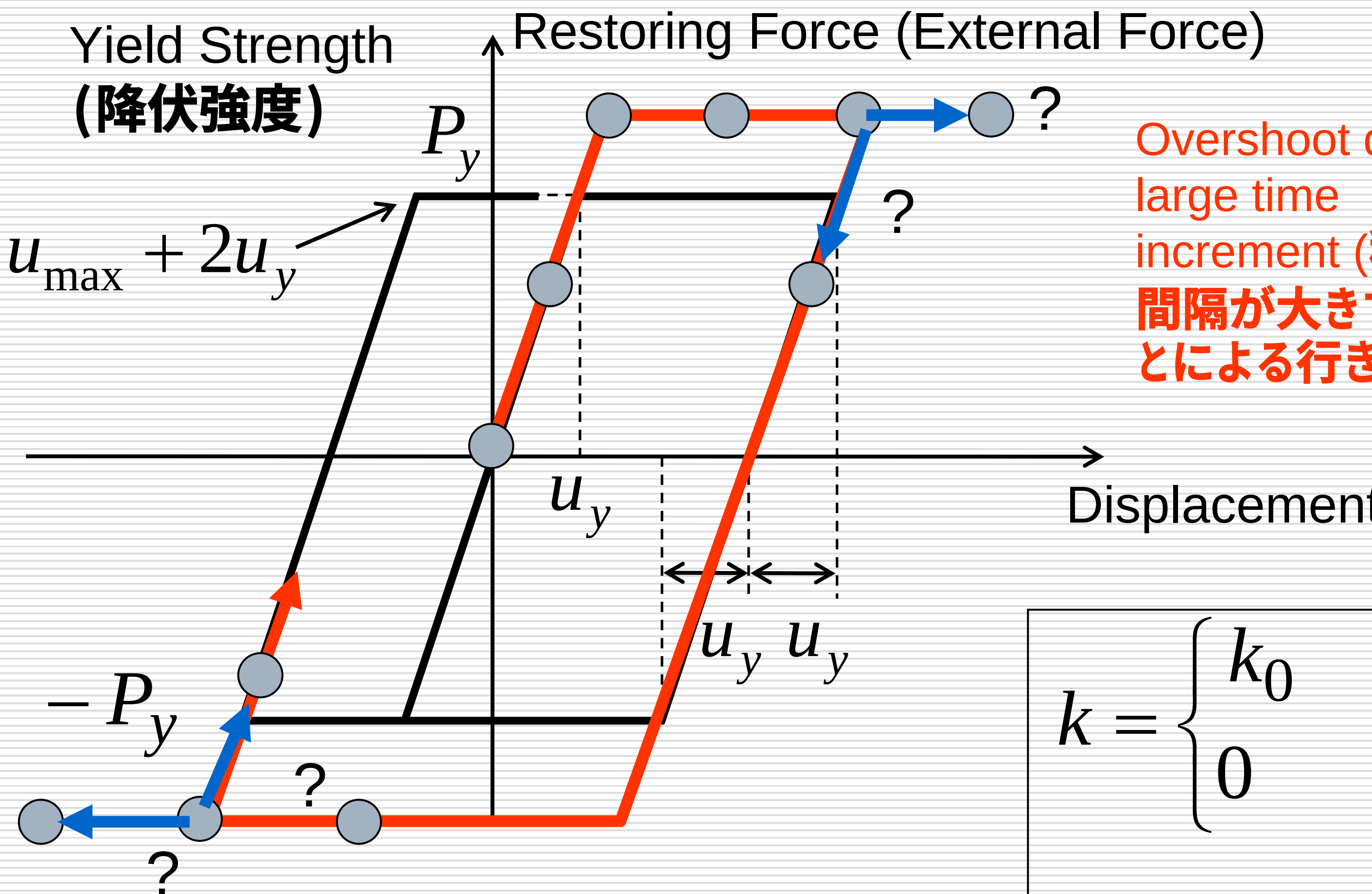
● Unloading from the plastic stage to the elastic stage can be controlled as

$$If \;\; R>0 \qquad \begin{array}{l} \Delta u \geq 0 \cdots\cdots k=0 \\ \Delta u < 0 \cdots\cdots k=k_0 (unloading) \end{array} \qquad \text{(E9.2a)}$$



$$k=\begin{cases} k_0 & |R|<P_y \\ 0 & |R|\geq P_y \end{cases} \qquad \text{(E9.1)}$$

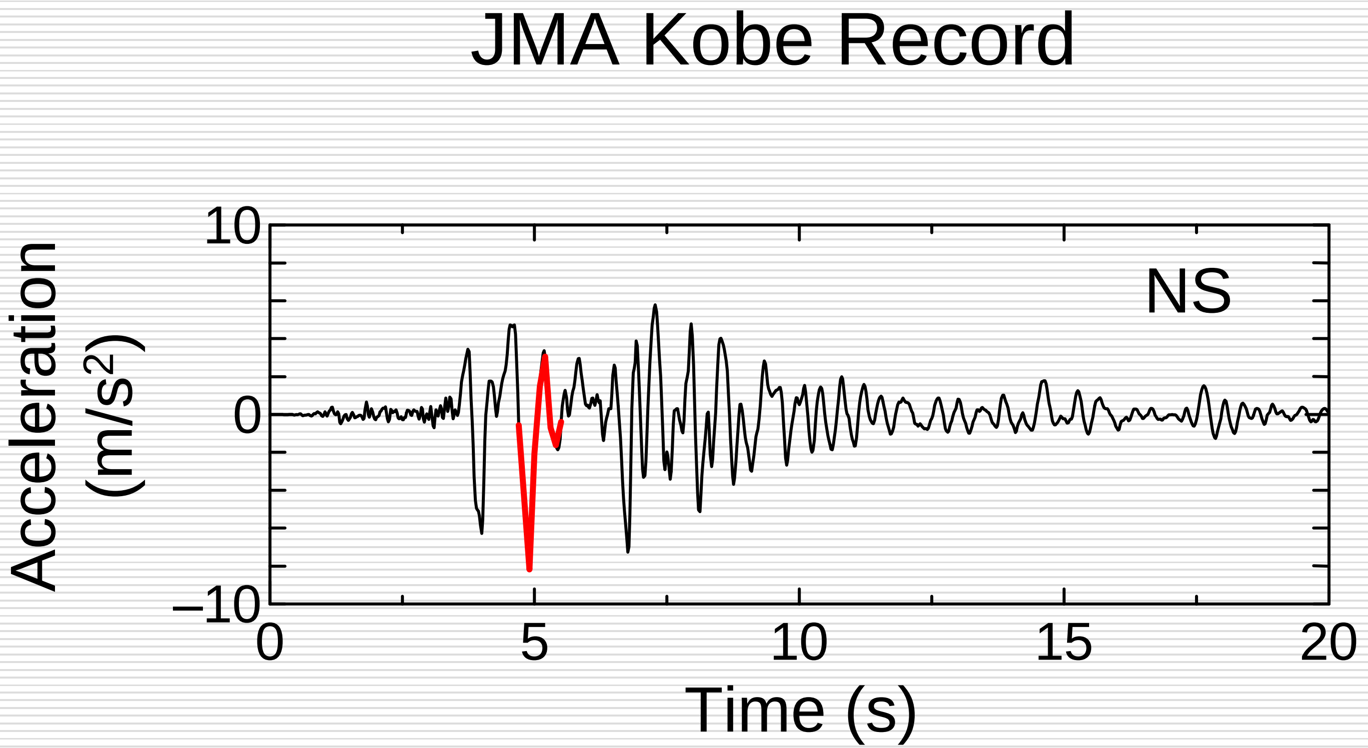
$$
\begin{aligned}
&If \;\; R<0 \quad \Delta u \le 0 \cdots\cdots k=0 \\
&\qquad\qquad\quad\;\; \Delta u > 0 \cdots\cdots k = k_0 (unloading)
\end{aligned}
\qquad \text{(E9.2b)}
$$



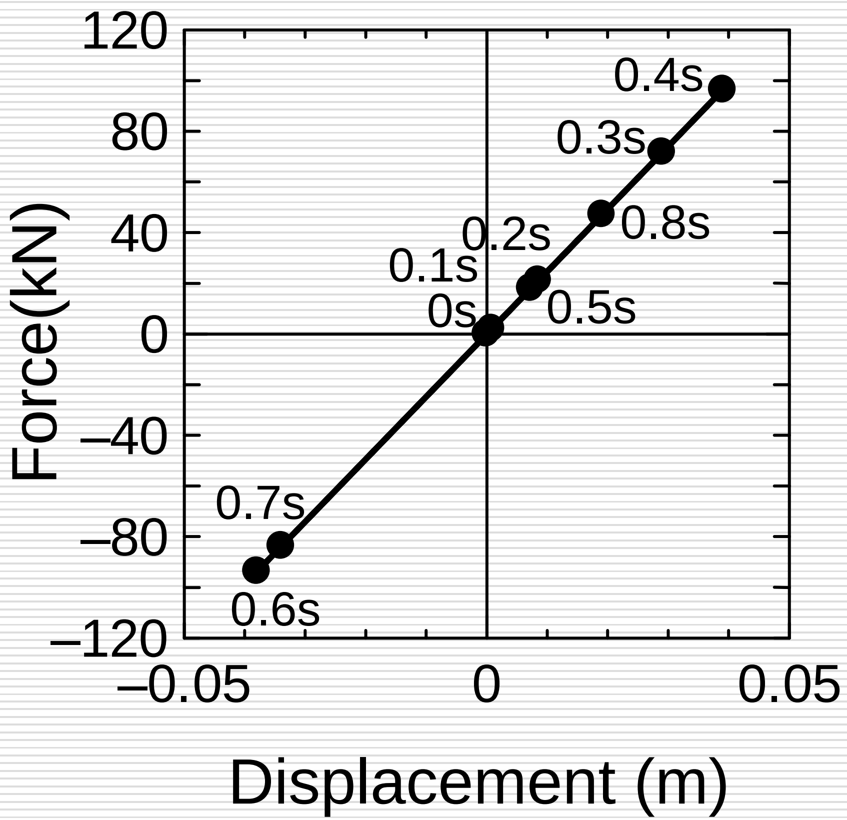
$$
k = \begin{cases} k_0 & |R| < P_y \\ 0 & |R| \ge P_y \end{cases}
$$

(E9.1)

Ground acceleration record applied to a SDOF system



Process of Linear Dynamic Response Analysis



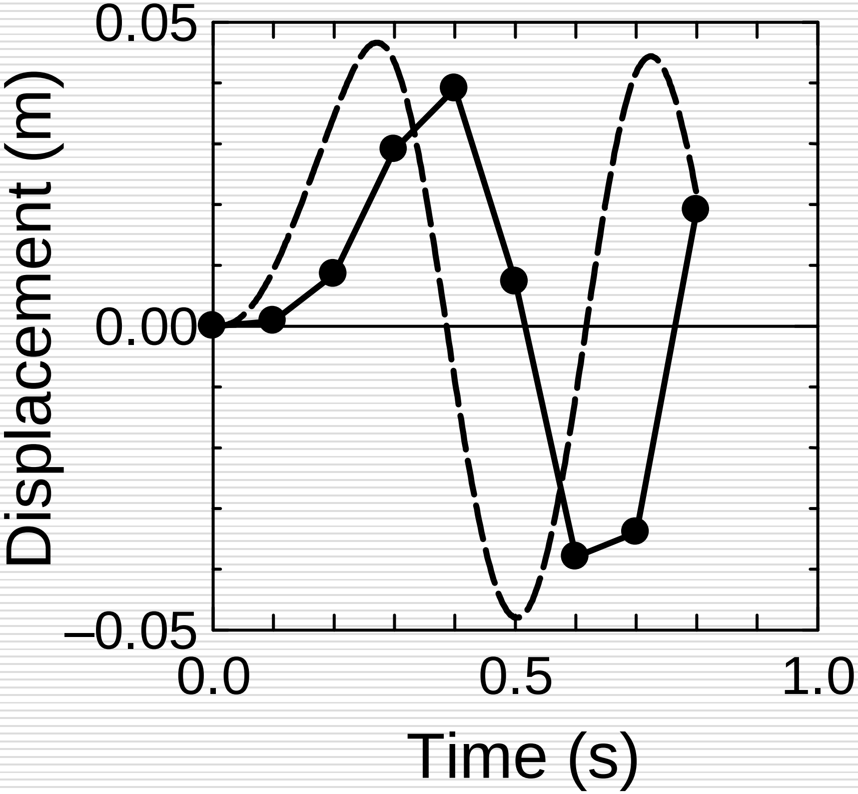
t	*u*(mm)	**Δ**	*k*	*R*(kN)
0	0	+	k_0	0
0.1	0.836	+	k_0	2.06
0.2	8.57	+	k_0	21.1
0.3	29.1	+	k_0	71.7
0.4	39.1	-	k_0	96.4
0.5	7.29	-	k_0	18.0
0.6	-38.0	+	k_0	-93.7
0.7	-33.9	+	k_0	-83.7
0.8	19.1	+	k_0	47.1

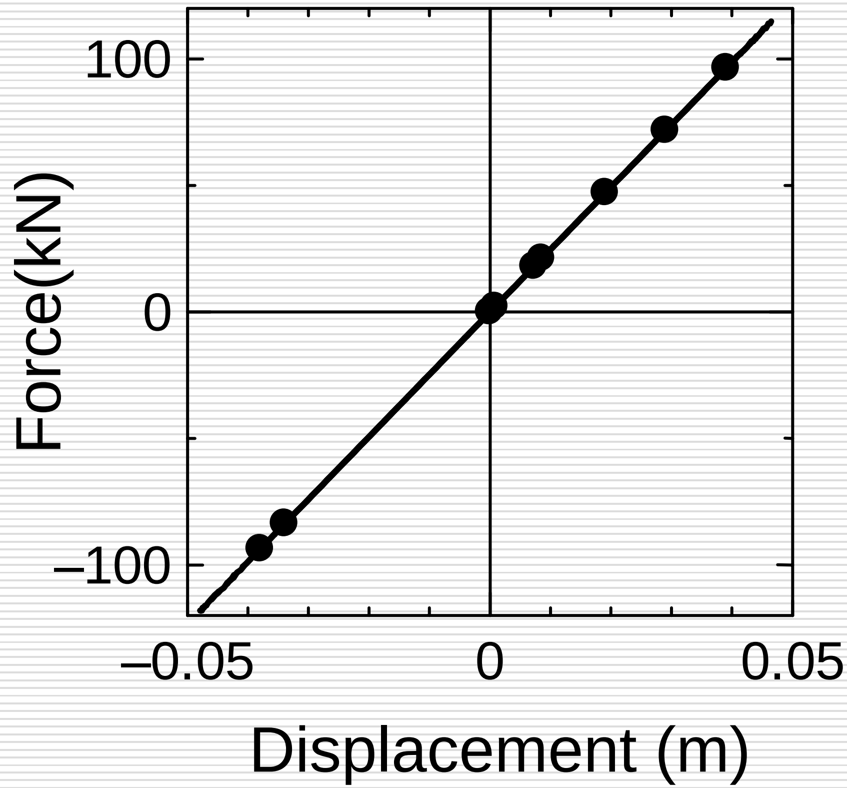
Linear Response of a SDOF System

———— $\Delta t = 0.1s$

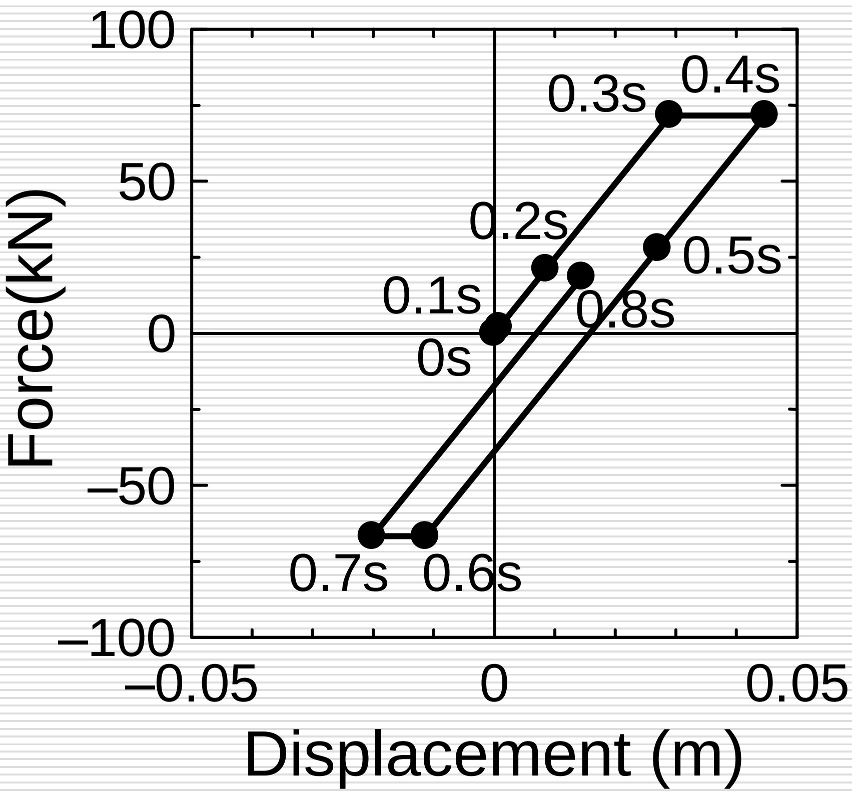
- - - - - - - $\Delta t = 0.002s$

T_0=0.4s





Process of Nonlinear Dynamic Response Analysis

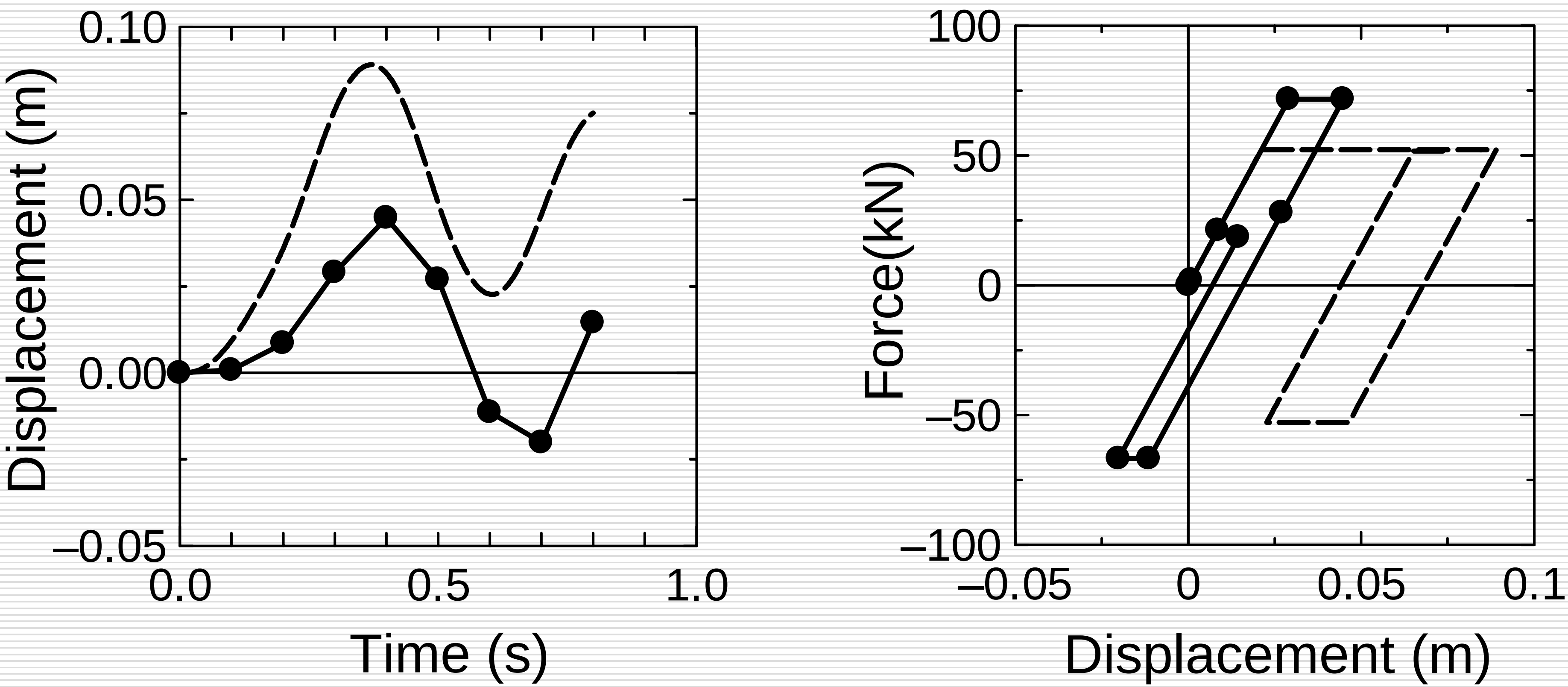


t	u(mm)	**Δ**	k	R(kN)
0	0	+	k_0	0
0.1	0.836	+	k_0	2.06
0.2	8.57	+	k_0	21.1
0.3	29.1	+	0	$71.7>P_y$
0.4	44.8	-	k_0	71.7
0.5	27.0	-	k_0	27.9
0.6	-11.3	-	0	$-66.8<-P_y$
0.7	-20.1	+	k_0	-66.8
0.8	14.5	+	k_0	18.6

Nonlinear Response of a SDOF System

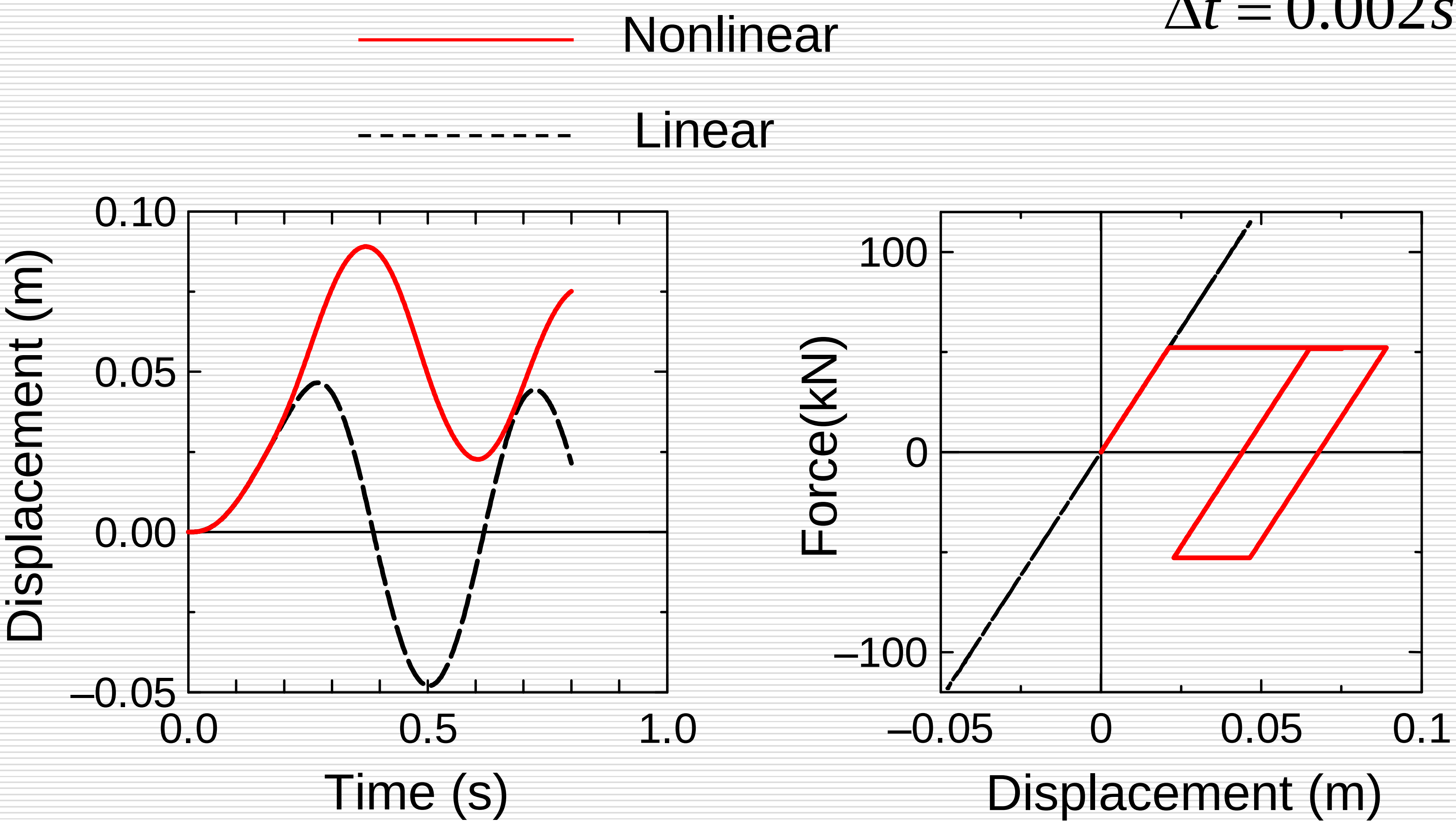
$\Delta t = 0.1s$ (solid line)

$\Delta t = 0.002s$ (dashed line)

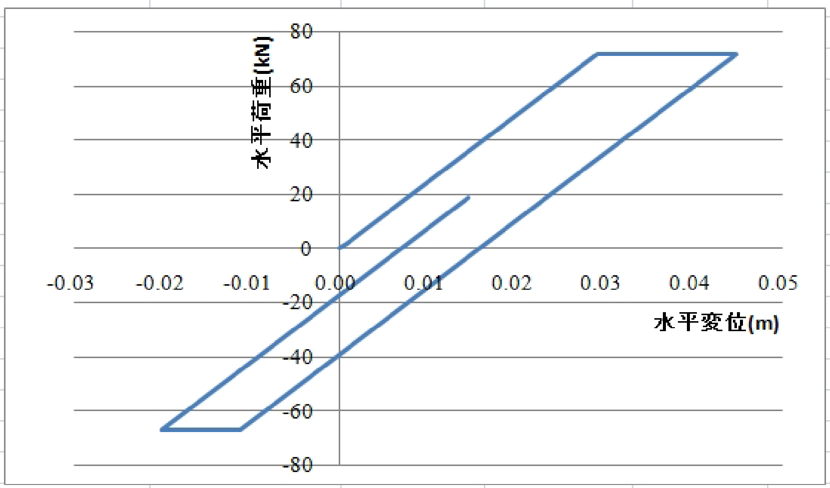


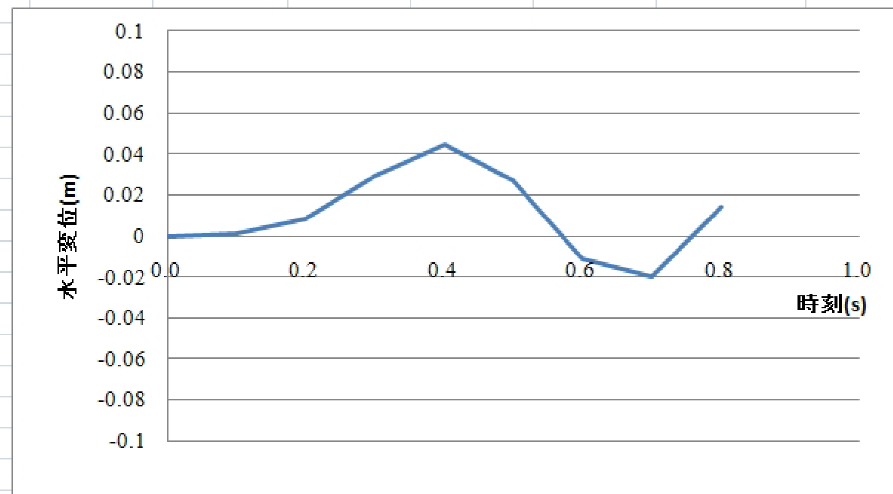
How does the response change between the linear and nonlinear calculation for a SDOF system?

$\Delta t = 0.002s$



時刻	地盤加速度	地盤加速度	変位	速度	加速度	剛性	減衰係数			変位増分	速度増分	加速度増分	復元力
t(s)	u_2dot_g(cm/s2)	u_2dot_g(m/s2)	u	u_dot	u_2dot	k	c	k_tilde	△p_tilde	△u	△u_dot	△u_2dot	Rf
0	-56.66	-5.67E-01	0.00E+00	0.00E+00	0.00E+00	2467.401	15.70796	6781.5604	5.67E+00	8.36E-04	1.67E-02	3.34E-01	0.00E+00
0.1	-442.161	-4.42E+00	8.36E-04	1.67E-02	3.34E-01	2467.401	15.70796	6781.5604	5.24E+01	7.73E-03	1.21E-01	1.76E+00	2.06E+00
0.2	-817.825	-8.18E+00	8.57E-03	1.38E-01	2.09E+00	2467.401	15.70796	6781.5604	1.39E+02	2.05E-02	1.34E-01	-1.51E+00	2.11E+01
0.3	-207.626	-2.08E+00	2.91E-02	2.72E-01	5.84E-01	0	15.70796	4314.1593	6.79E+01	1.57E-02	-2.29E-01	-5.74E+00	7.17E+01
0.4	148.424	1.48E+00	4.48E-02	4.29E-02	-5.16E+00	2467.401	15.70796	6781.5604	-1.20E+02	-1.77E-02	-4.41E-01	1.51E+00	7.17E+01
0.5	304.92	3.05E+00	2.70E-02	-3.98E-01	-3.65E+00	2467.401	15.70796	6781.5604	-2.60E+02	-3.84E-02	2.78E-02	7.86E+00	2.79E+01
0.6	-70.684	-7.07E-01	-1.13E-02	-3.70E-01	4.21E+00	0	15.70796	4314.1593	-3.78E+01	-8.77E-03	5.64E-01	2.87E+00	-6.68E+01
0.7	-162.058	-1.62E+00	-2.01E-02	1.94E-01	7.08E+00	2467.401	15.70796	6781.5604	2.35E+02	3.46E-02	3.03E-01	-8.10E+00	-6.68E+01
0.8	-38.78	-3.88E-01	1.45E-02	4.97E-01	-1.02E+00	2467.401	15.70796	6781.5604	1.82E+02	2.68E-02	-4.58E-01	-7.13E+00	1.86E+01





Excel-base dynamic response analysis program

	Linear	Nonlinear (Elastoplastic)
Manual	LDRA-1	NLDRA-1
	(Same program)	
Auto	LDRA-2	NLDRA-2

Developed by H. Matsuzaki