PRISM for Earthquake Engineering

A Program for seismic response analysis of SDOF systems

User Manual

Version 2.0.0

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Contents

1. Introduction

PRISM is a program for seismic response analysis of single-degree-of-freedom systems. It is capable of (i) processing and filtering earthquake ground motions, (ii) calculating response-histories of a structure with various hysteresis models, and (iii) generating elastic and inelastic response spectra. Scaling, cropping and baseline correction can be performed on earthquake records prior to time-integration. Numerical and graphical results can be exported to the clipboard.

System requirements for PRISM:

- Windows® XP/Vista/7/8
- 512MB or more available ram space
- 100MB or more available hard disk space
- 1280x800 or more higher resolution

Main features of PRISM are as follows:

- Processing earthquake ground motions [Fig. 1.1]
  · Scaling and cropping
  · Baseline correction
  · Noise filtering
  · Monitoring arias intensity

- Dynamic response history analysis [Fig. 1.2]
  · Numerical and graphical results on acceleration, velocity and displacement
  · Monitoring force-displacement relationship of an inelastic structure
  · Inelastic dynamic analysis with various hysteresis curves
  Linear elastic, Bi-linear, Tri-linear, Bouc-Wen, Modified Takeda, and Al-Bermani models can be used.

- Response spectra [Fig. 1.3]
  · Elastic response spectra with various viscous damping values
  · Inelastic response spectra with various ductility demands
  · Numerical and graphical results in various formats including the ADRS (Acceleration-Displacement Response Spectrum).

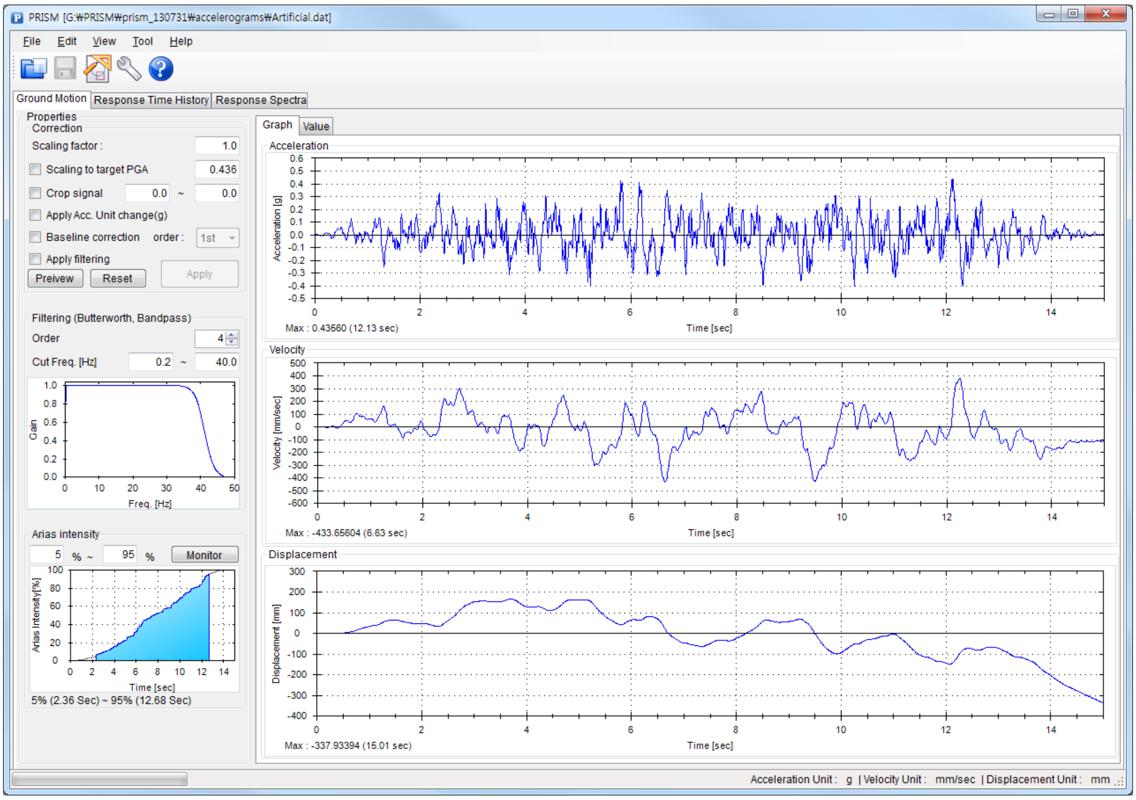


Fig. 1.1 Ground Motion Menu

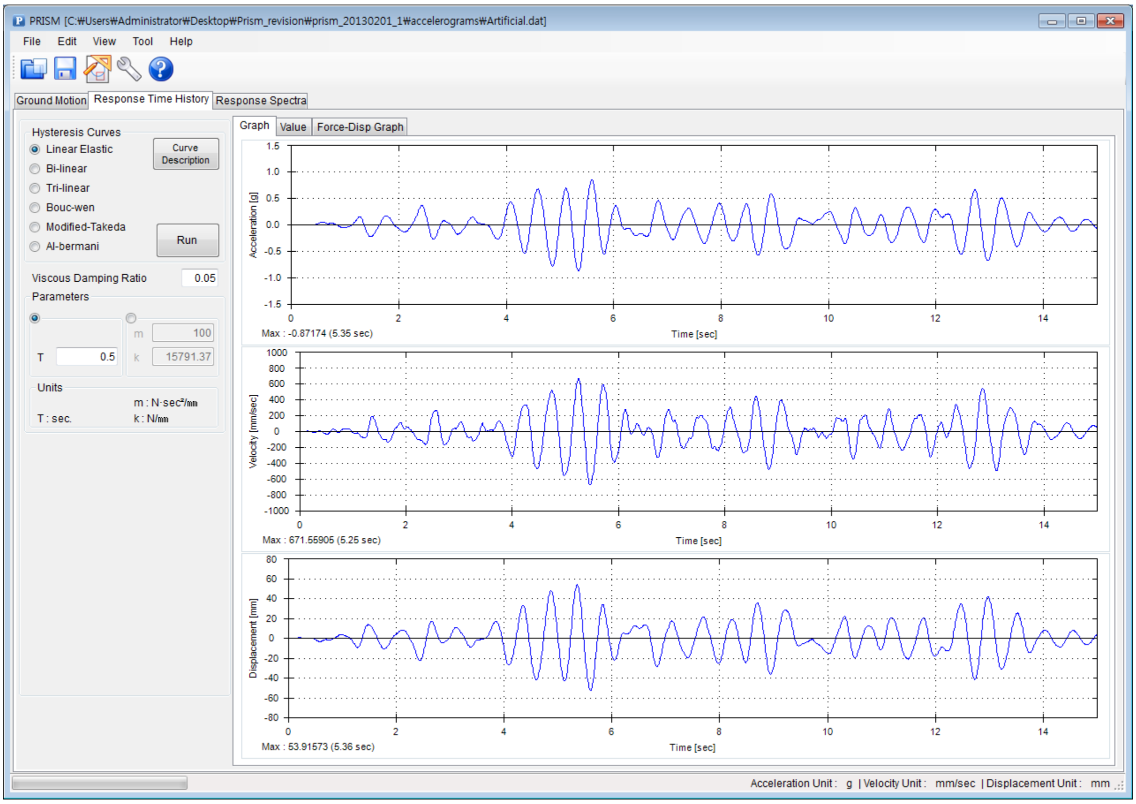


Fig. 1.2 Response Time History Menu

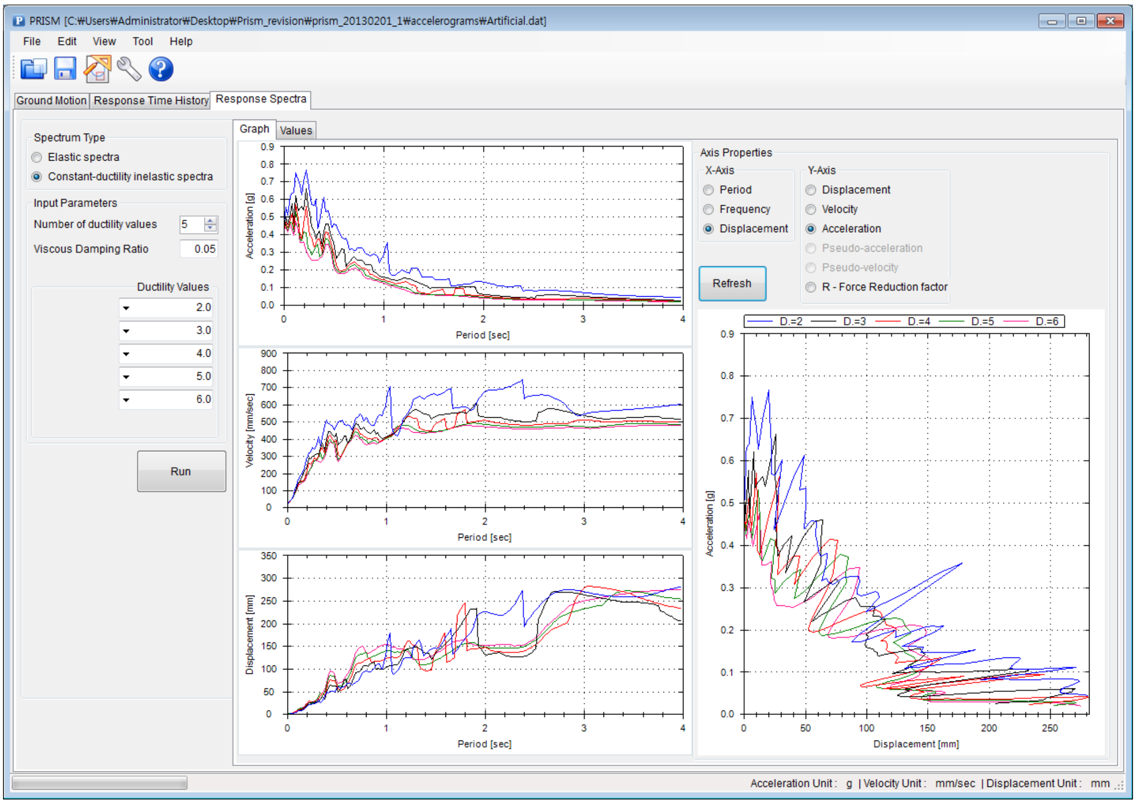


Fig. 1.3 Response Spectra Menu

Prism is developed to provide engineers, researchers and students with a tool to easily investigate seismic responses of structures. Users may make and distribute unlimited copies of the program in its original form. The free PRISM license expires on 31 December of each year, and new version can be downloaded on 1 January of the following year.

2. Ground motion

PRISM can read accelerograms saved in two most-widely used formats as follows:

(1) Format 1: 1st column for time and 2nd column for acceleration

[Fig. 2.1]

(2) Format 2: NGDC (National Geographical Data Center of NOAA) or NGA (Next Generation Attenuation Model) [Fig. 2.2]

Once an accelerogram has been imported, the corresponding velocity and displacement time-histories are automatically computed and plotted in the main window. Prism provides a convenient feature for correcting accelergrams such as scaling, cropping the signal and baseline correction.

2.1 Properties

No. of Raw data line : The number of acceleration data points

2.2 Correction

Scaling to target PGA : Magnify the given accelerogram

Crop Signal : Truncate the given accelerogram

Baseline Correction : By default, baseline correction of time-history is not carried out before integration. The user can decide whether this operation is to be carried out or not. Further information and discussion on baseline correction can be found in the work by Chiu.

Unit change : When user saves the values, saved the values in unit that has been converted.

Apply Filtering : Device for filtering a value of the noise occurred by the ambient vibration.

2.3 Arias Intensity

Arias Intensity : A measure of the strength of a ground motion. It was proposed by Chilean engineer Arturo Arias in 1970. I_A (Arias Intensity) is derived from the integration of the square of the entire acceleration record; thus, I_A includes the characteristics of amplitude, frequency content and duration of ground motion

$$I_A = \frac{\pi}{2g}\int_0^{T_d} a(t)^2 dt \quad (m/s)$$

Where, g is the acceleration due to gravity

T_d is the duration of signal above threshold

2.4 Filtering (Butterworth, Bandpass)

Order : Degree of equation define expression mode of curve. Polynomials of up to the 8th order may be used.

Cut Freq [Hz] : Determine the cut-off frequency of the bandpass filter.

References

Chiu, H.-C., "Stable baseline correction of digital strong-motion data", Bulletin of the Seismological Society of America, V.87 (4), p932-944, 1997

Arias, A., "A measure of earthquake intensity", In : Hansen, R.J. (Ed.), Seismic Design for Nuclear Power Plants, MIT Press, Cambridge, MA, p.438-483

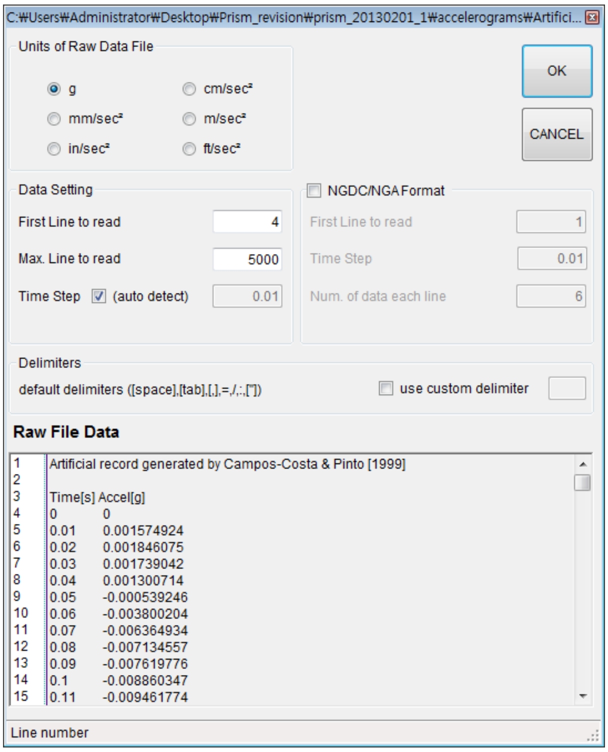


Fig. 2.1 Accelerogram format 1

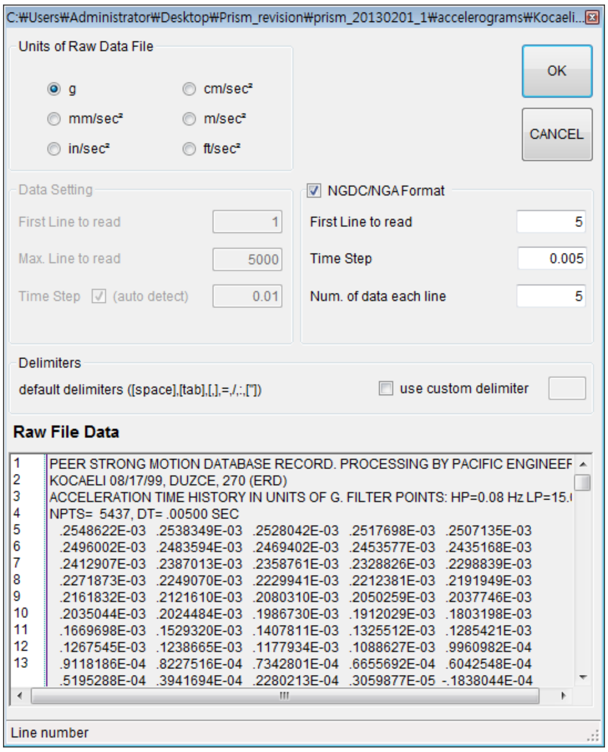


Fig. 2.2 Accelerogram format 2

3. Response Time History

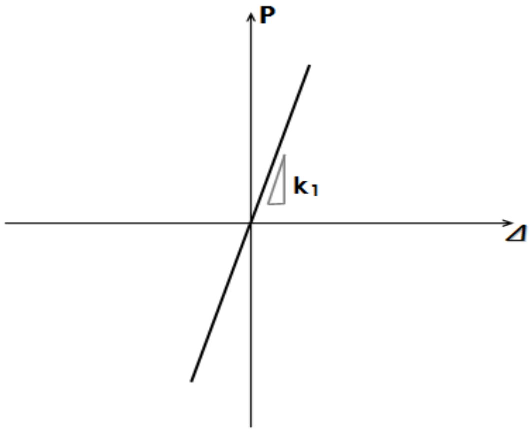
PRISM includes a variety of hysteretic models.

Hysteretic model	Description
Linear Elastic	: The default model. No hysteretic behavior.
Bi-linear	: The simplest hysteretic model with no or some stiffness exhibited after yield.
Tri-linear	: The hysteretic model with two post yield stiffnesses.
Bouc-Wen	: A smooth hysteretic model which is very popular because of its versatility and simplicity.
Modified Takeda	: This is used to model plastic hinges in reinforced concrete beams / columns.
Al-Bermani	: A simple loop used to represent steel behavior.

3.1 Linear Elastic model

• Number of parameters : 1

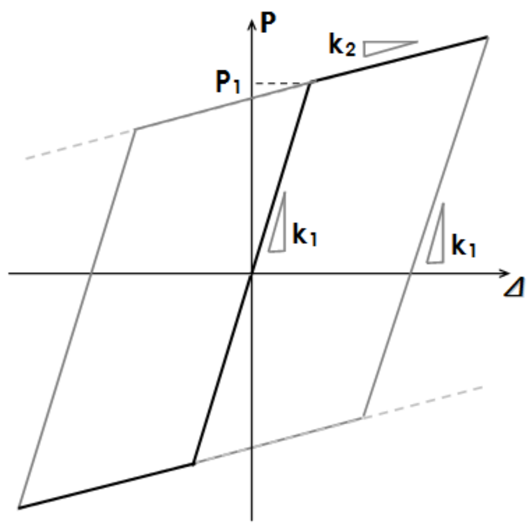
Parameter	Description	Equation
T	Period (sec)	$T = 2\pi\sqrt{\frac{m}{k_1}}$



3.2 Bi-linear model

• Number of parameters : 3

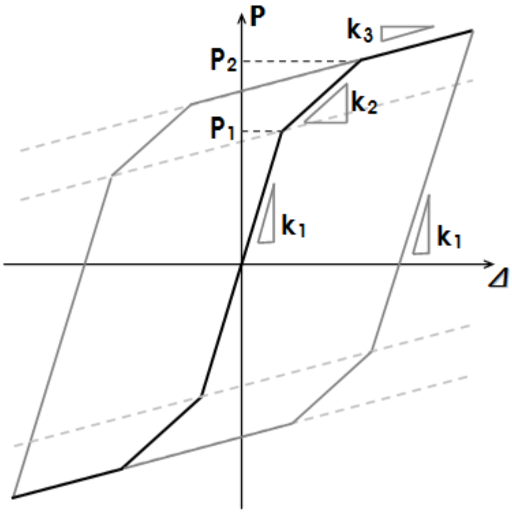
Parameters	Description	Equation
T	Period (sec)	$T = 2\pi\sqrt{\frac{m}{k_1}}$
SR	Strength ratio on P_1	$SR = \frac{P_1}{mg}$
α	Post-to-pre yield stiffness ratio	$\alpha = \frac{k_2}{k_1}$



3.3 Tri-linear model

• Number of parameters : 5

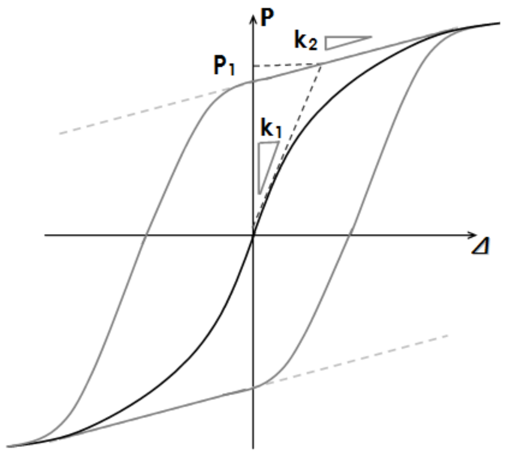
Parameters	Description	Equation
T	Period (sec)	$T = 2\pi\sqrt{\frac{m}{k_1}}$
SR_1	Strength ratio on P_1	$SR_1 = \frac{P_1}{mg}$
SR_2	Strength ratio on P_2	$SR_2 = \frac{P_2}{mg}$
α_1	Pre-to-post stiffness ratio of second branch	$\alpha_1 = \frac{k_2}{k_1}$
α_2	Pre-to-post stiffness ratio of third branch	$\alpha_2 = \frac{k_3}{k_1}$



3.4 Bouc-Wen model

• Number of parameters : 7

Parameters	Description	Equation
T	Period (sec)	$T = 2\pi\sqrt{\frac{m}{k_1}}$
SR	Strength ratio on P_1	$SR = \frac{P_1}{mg}$
α	Post-to-pre yield stiffness ratio	$\alpha = \frac{k_2}{k_1}$
A, β, γ, n	Parameters which control the hysteresis	



$$P(t) = \alpha k u(t) + (1-\alpha)P_1 z(t) \quad , \quad \dot{z}(t) = \frac{A\dot{u}(t) - [\beta|\dot{u}(t)||z(t)|^{n-1} z(t) + \gamma \dot{u}(t)|z(t)|^n]}{d_y}$$

where, d_y : yield displacement

Reference

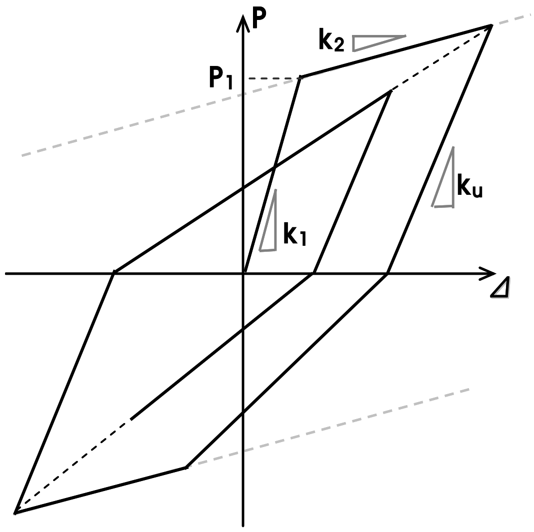
R. Bouc. “Forced vibration of mechanical systems with hystereis”, Proceedings of the Fourth Conference on Non-linear oscillation, Prague, Czechoslovakia, 1967

Y. K. Wen, “Method for random vibration of hysteretic systems”, Journal of the Engineering Mechanics Division, V.102, No.2, 249-263, 1976

3.5 Modified Takeda model

• Number of parameters : 4

Parameters	Description	Equation
T	Period (sec)	$T = 2\pi\sqrt{\frac{m}{k_1}}$
SR	Strength ratio on P_1	$SR = \frac{P_1}{mg}$
α	Post-to-pre yield stiffness ratio	$\alpha = \frac{k_2}{k_1}$
q	Unloading stiffness ratio	$k_u = k_1\left(\frac{d_y}{d_{\max}}\right)^q$



Reference

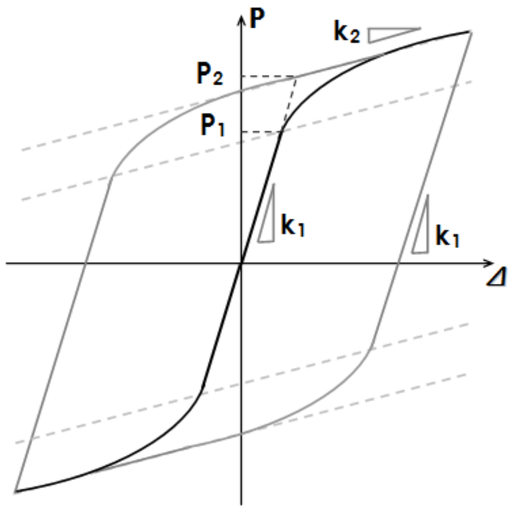
S. Otani, "Inelastic analysis of R/C frame structures", ASCE J. of Struct. Div. V.100, p1433-1449, 1974

3.6 Al-Bermani model

• Number of parameters : 4

• A simple hysteresis used to represent steel behavior.

Parameters	Description	Equation
T	Period (sec)	$T = 2\pi\sqrt{\frac{m}{k_1}}$
SR	Strength ratio on P_2	$SR = \frac{P_2}{mg}$
α	Post-to-pre yield stiffness ratio	$\alpha = \frac{k_2}{k_1}$
η	The ratio of yield strength ($\eta \leq 1$)	$\eta = \frac{P_1}{P_2}$



Reference

K. Zhu, F. G. A. Al-Bermani, S. Kitipornchai and B, Li, “Dynamic response of flexibly jointed Frames”, Engineering Structures, V.17, No.8, p575-580, 1995

4. Response Spectra

Elastic and Inelastic response spectra are computed by means of the Newmark time integration method. The parameters of the Newmark method can be modified in the setting menu of the program. Users can define up to five different levels of viscous damping ratio. Inelastic spectra are calculated based on bi-linear oscillators and post-yield stiffness ratio can be modified in the setting menu of the program. By default, post-yield stiffness ratio is 0 (Elastic Perfectly Plastic hysteresis). The user can modify the post-yield stiffness ratio between 0 and 1.0. Up to five target ductility values can be given for the calculation of inelastic spectra. In the calculation, if more than one R-factor (Force reduction factor) corresponds to a given ductility value, the smallest factor is chosen. After determining the input parameters (viscous damping ratio and ductility value), users needs to click “Run” button to commence the required calculation. The minimum and maximum periods of the spectra are 0.02 and 4.0 seconds, respectively.

5. Setting

This program modifying function is available from the Setting screen. User can access through Tool > Setting or through toolbar button.

The program may define the number of decimal points to be used in the display of results. Further, it will stop if the displacement is larger than the limit displacement. [Fig. 5.1]

The program provides an option to guarantee the accuracy of the analysis results by limiting the integration time step as small enough to avoid numerical errors. The ratio of dt/T (integration time step to the period of a structure) needs to be less than a certain value to reduce numerical errors. This limitation is useful only for oscillators with very short periods. While the program’s default option is off (not to apply the limitation) for the rapid process, users can apply the limit by marking the check box in the setting menu as shown in the below figure. [Fig. 5.2]

For the computation of constant-ductility spectra by bilinear curves, the post-yield stiffness ratio needs to be defined. Further, when accomplish bilinear analysis, it is required for a convergence criterion to be set, in order for the bilinear analysis to progress from one step to the other. For this reason, a 'Convergence tolerance' is defined, with default values amply small to warrant very good accuracy. If users wish to speed, their analysis may obviously define larger convergence tolerance values. [Fig. 5.3]

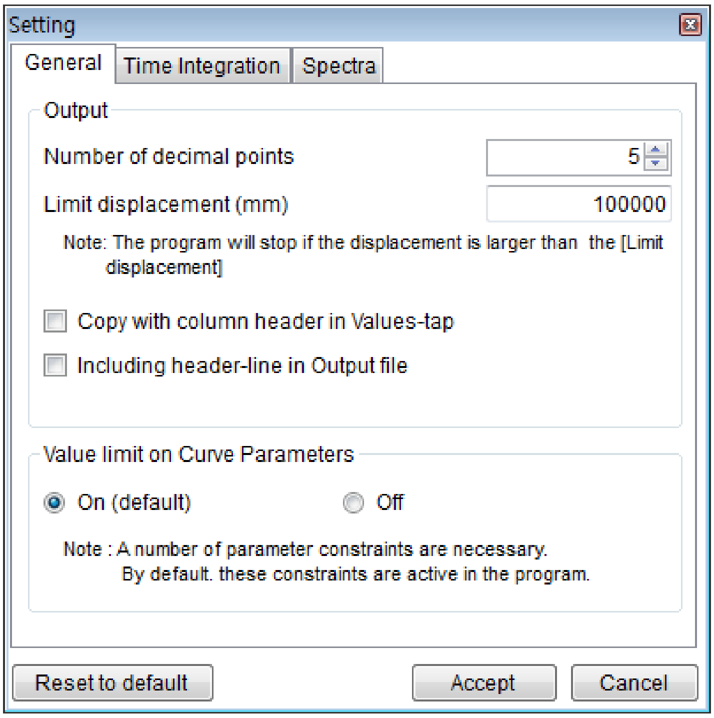


Fig. 5.1 Setting General

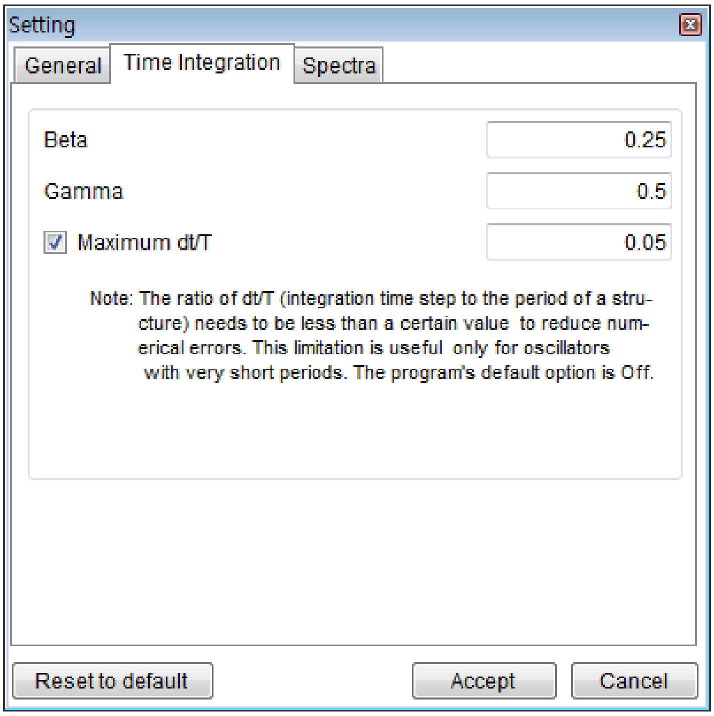


Fig. 5.2 Setting Time Integration

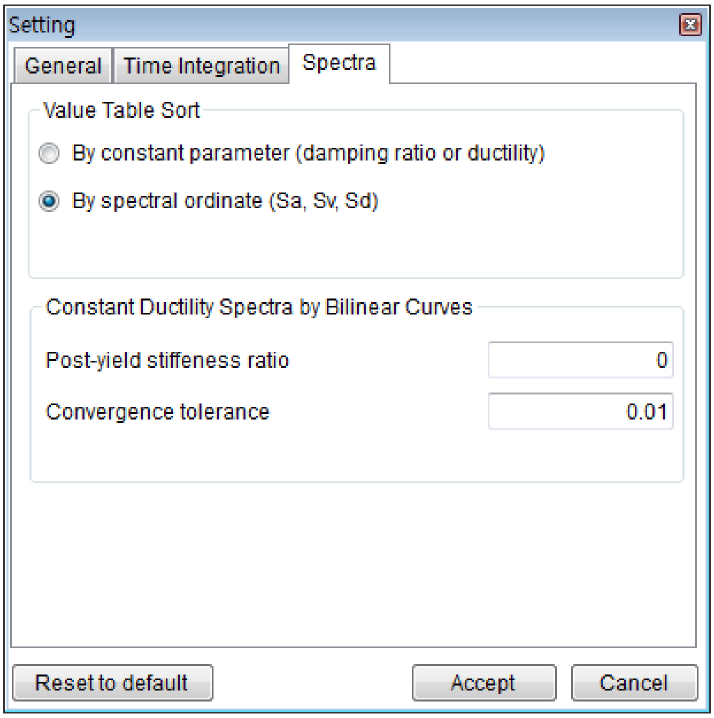


Fig. 5.3 Setting Spectra