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Department of Civil Engineering

COMPUTER PROGRAM LIBRARY

Program name:– **SIMQKE**	Program type:– Fortran Format Printing	Program code:– ANSI Fortran77
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SIMQKE

A PROGRAM FOR ARTIFICIAL MOTION GENERATION

The program **SIMQKE** has these major capabilities:

- It computes a power spectral density function from a specified smooth response spectrum.
- It generates statistically independent artificial acceleration time histories and tries, by iteration, to match the specified response spectrum.
- It performs a baseline correction on the generated motion to ensure zero final ground velocity.
- It calculates response spectra with the time histories as input.

BRIEF DESCRIPTION OF THE MOTION GENERATION PROCEDURE

An explanation of the input to **SIMQKE** and complete flowchart (Fig. 1) are given.

The method used by the program for artificial ground motion generation is based on the fact that any periodic function can be expanded into a series of sinusoidal waves:

$$X(t) = \sum_n A_n \sin\left(\omega_n t + \phi_n\right) \tag{1}$$

where A_n is the amplitude and N_n is the phase angle of the n^{th} contributing sinusoid. By fixing an array of amplitudes and generating different arrays of phase angles, one obtains different motions with the same general appearance but different details. The computer program uses a random number generator to produce strings of phase angles with uniform likelihood in the range between 0 and 2B.

The amplitudes A_n are related to the (one-sided) spectral density function G(T) in the following way:

$$G(\omega_n)\Delta\omega = \frac{A_n^2}{2} \tag{2}$$

Since the total power may be expressed as:

$$\Sigma \, A\frac{n^2}{2} = \Sigma \, G(\omega_n)\Delta\omega \rightarrow \int_o^\infty G(\omega)d\omega \tag{3}$$

where $G(T_n)$) T may be interpreted as the contribution to the total power of the motion from the sinusoid with frequency T_n. Allowing the number of sinusoids in the motion to become very large, the total power will become the area under the continuous curve G(T).

The power of the motion produced by using equation 1 does not vary with time. To simulate the transient character of real earthquakes, the steady-state motions are multiplied by a deterministic envelope function I(t). The artificial motion Z(t) then becomes:

$$Z(t) = I(t) \sum_n A_n \sin(\omega_n t + \phi_n) \tag{4}$$

The resulting motion is stationary in frequency content with a peak acceleration close to the target peak acceleration. This program has incorporated three different intensity envelope functions such as the "Trapezoidal" envelope (Hou, 1968), the "Exponential" envelope (Lio, 1969) and the "Compound" envelope (Jennings, 1968) functions as shown in Fig. 2. The program artificially raises or lowers the generated peak acceleration to match exactly the target peak acceleration.

The response spectra corresponding to the motion (4) are then computed. The response spectrum for one chosen damping value is called the "target" response spectrum which the programme will attempt to "match" the input spectrum.

To smoothen the calculated spectrum and to improve the matching, an iterative procedure is implemented. In each cycle of the iteration, the calculated response is compared with the target at a set of control frequencies (the user specifies the number of control frequencies). The ratio of the desired response to the computed response is obtained at each control frequency and the corresponding value of the power spectral density is modified in proportion to the square of this ratio, i.e., at any cycle i:

$$G(\omega)_{i+1} = G(\omega)_i \left(\frac{S_v^{(\omega)}}{S_{v(\omega)}^{(i)}} \right)^2 \tag{5}$$

where S_v is the target spectral value. With the modified spectral density function a new motion is generated and a new response spectrum is calculated. The procedure should not be expected to be convergent at all control frequencies; the response at a control frequency is dependent not only on the spectral density function value for that frequency, but also on other values at frequencies close to the frequency of interest as well. Usually, it is not productive to iterate for more than about 4 cycles. If an adequate level of agreement cannot be reached, the user is advised to "start fresh" by generating an entirely new motion (with a new set of random phase angles). For more elaborate explanation of some features of the programme, the reader is referred to Gasparini and Vanmarcke (1976)*.

*Gasparini, D. and Vanmarcke, E.H., "Simulated Earthquake Motions Compatible with Prescribed Response Spectra", M.I.T. Department of Civil Engineering Research Report R76-4, Order No. 527, January 1976.

Running the program SIMQKE.

To run the program call the program by the method appropriate to your operating system. On a personal computer just type **SIMQKE** assuming that the files **SIMQKE.EXE** and the associated **.DLL** and **.HLP** files are in your current directory or path.

In Microsoft Windows operating systems another option is to create a shortcut on the desktop and for this purpose a suitable icon for SIMQKE, **Simqke.ico**, is supplied with the program.

The program prompts for responses to a series of questions. Default responses, where appropriate, are enclosed in square brackets, **[ ]**. File names must match the conventions of your operating system but file names, with paths where necessary, must not exceed 60 characters in length and must not contain blanks.

The first question asks for the name of the output file. The default is the computer console or terminal screen. This is normally the response for most users, however if an output file is created then the envelope values of each graph line drawn is output to that file.

To get hard copies of the plots.

In Microsoft Windows operating systems get hard copies of the graphs use the pull down 'file' menu and select the Print or Save options to send the graph to the printer or to save the plot as a bitmap file (**.BMP)**.
On unix systems using GKS graphics select the Hard-copy option from the Choice window

Note: In the following user guide, each line of required data is indicated by a box containing the data items. Below each box is a description of the data items. The data items on each line may be separated by commas or blank spaces. The format for the items are indicated by the letter at the end of each descriptive line with **A** indicating a character string, **I** indicating an integer value and **F** indicating a floating point number. A floating point number may or may not have a decimal point and may also take a scientific or exponent form such as 1.5E6 which could also be expressed as 1500000.0. Character strings will be upper-cased unless enclosed in double or single quotes and will terminate at the first blank space unless the string is enclosed in quotes.

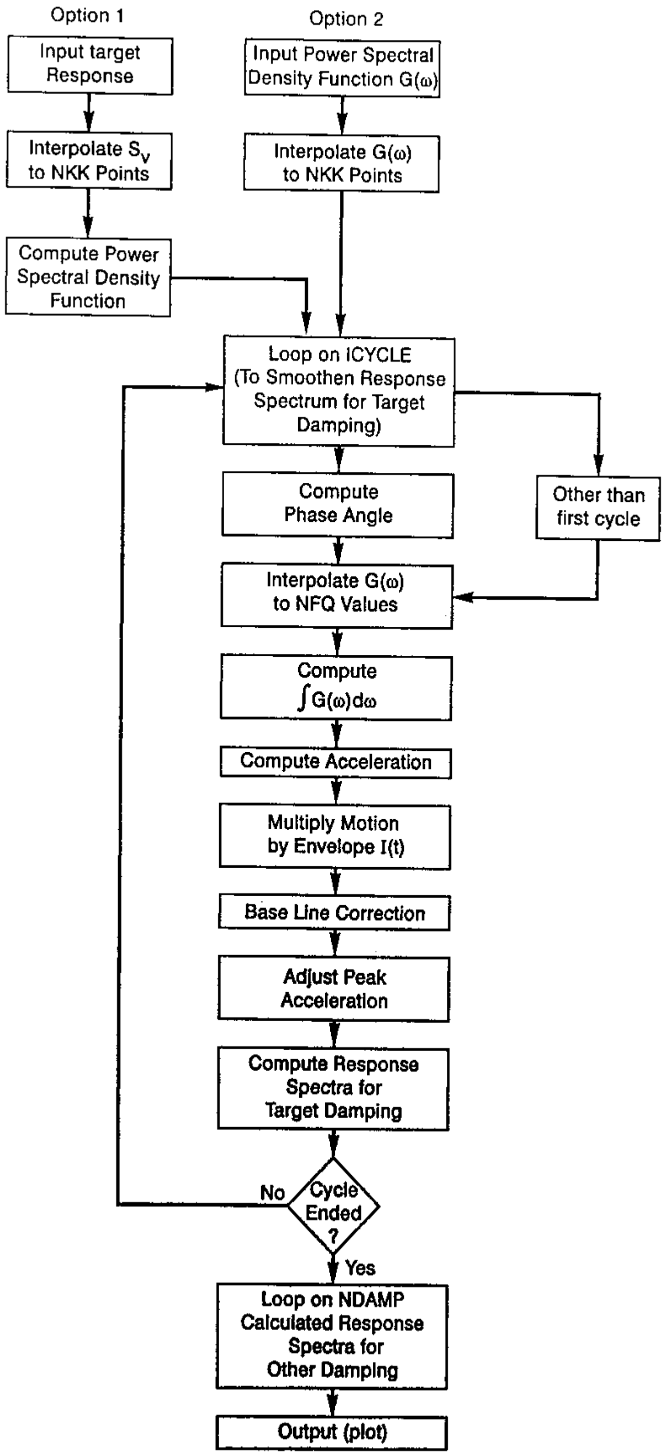

Figure 1. Flowchart for SIMQKE

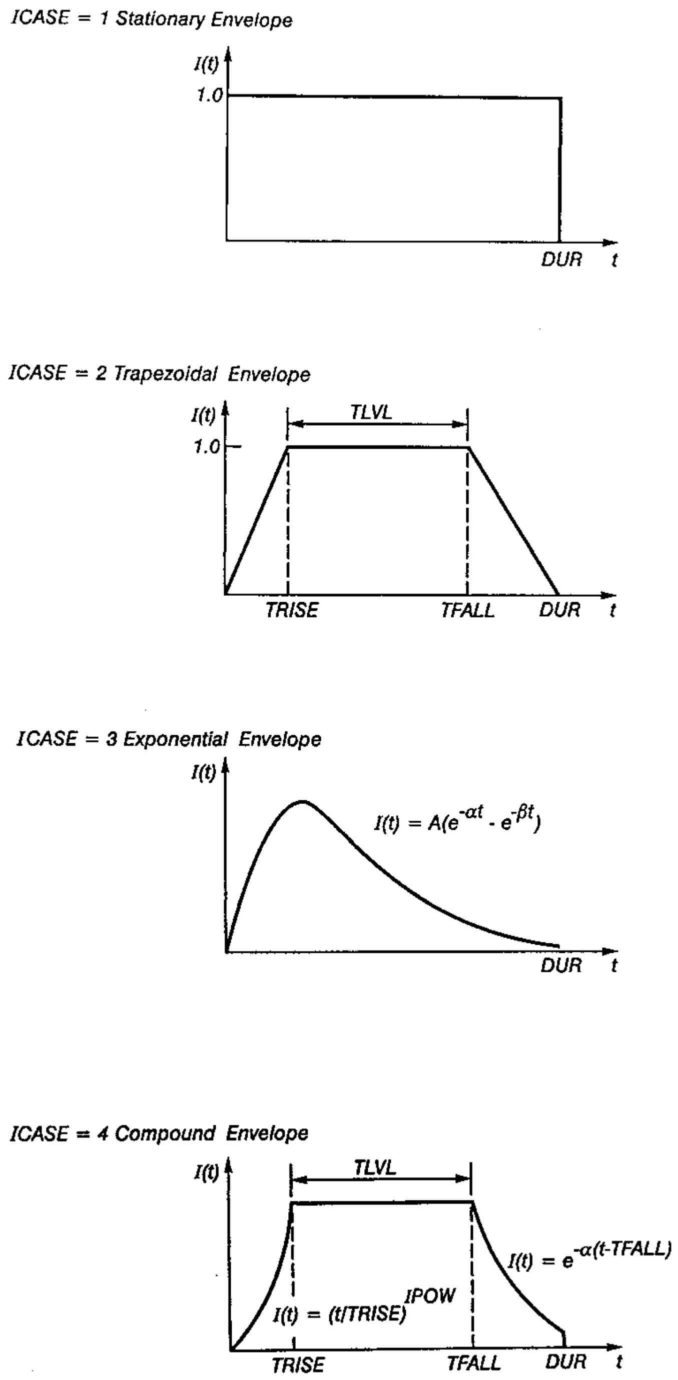

Figure 2. Intensity Envelopes

1. Name for the Artificial Record.

This name may be more explanatory than the file name requested by the opening routines.

NAME

NAME	Name for the Artificial Earthquake (Maximum of 72 characters)	**A**

Note: If the name contains blank spaces or lower case characters enclose the response in single or double quotes. e.g. "Artificial NZS 4203"

2. Frequency Envelope Parameters.

TS TL TMAX TMIN GRAV ISPEC

TS		Shortest Period of desired Response Spectrum	(seconds)	**(>0.0)**	**F**
TL		Longest Period of desired Response Spectrum	(seconds)		**F**
TMIN		Minimum Period for range of Simulation **TMIN $ TS**. If = 0.0 then **TMIN=TS**	(seconds)		**F**
TMAX		Maximum Period for range of Simulation **TMAX# TL**. If = 0.0 then **TMAX=TL**	(seconds)		**F**
GRAV		Acceleration of Gravity	(length/sec/sec)		**F**
ISPEC	=0:	Psuedo Spectral Velocity	(length/sec)		**I**
	=1:	Spectral Acceleration	(gravity units)		

Note: The parameter **TS** must be greater than zero as logarithmic interpolation is used in the calculations.

3. Acceleration Time Envelope Parameters.

ICASE DUR TRISE TLVL A ALFA BETA IPOW

ICASE	=1;	Stationary Envelope Parameters			**I**
	=2;	Trapezoidal Envelope Parameters			
	=3;	Exponential Envelope Parameters			
	=4;	Compound Envelope Parameters			
DUR		Accelerogram Duration	(Seconds)		**F**
TRISE		Accelerogram Rise Time	(Seconds)	(**ICASE** 2 or 4)	**F**
TLVL		Accelerogram Level Time	(Seconds)	(**ICASE** 2 or 4)	**F**
A		Exponential Factor		(**ICASE** 3)	**F**
ALFA		Exponential Factor		(**ICASE** 3 or 4)	**F**
BETA		Exponential Factor		(**ICASE** 3)	**F**
IPOW		Exponential Power Factor		(**ICASE** 4)	**I**

Note: See Figure 2 for the definition of terms and the implied time envelopes. Supply zero values for those items not used for a specific **ICASE**.

4. Accelerogram Control Data.

DELT AGMX RAN NDAMP NCYC NKK NRES NGWK IPCH

DELT	Time Step for Accelerogram (Seconds) (Usually 0.02 or 0.01)	**F**
AGMX	Maximum Acceleration (Gravity)	**F**
RAN	Random Number for Seed purposes (Odd number)	**I**
NDAMP	Number of Damping Ratios for final Spectrum (1#**NDAMP**#5)	**I**
NCYC	Number of Cycles of Iteration to smoothen spectra match. Experience has shown little improvement for **NCYC** > 5. **NCYC**=1 implies no iteration.	**I**
NKK	Number of Response Spectral Points at equal intervals between **TMIN** and **TMAX** (Maximum is 300, Usually 200 to 300).	**I**
NRES	Number of points to define input Target Spectrum or Spectral Density Function	**I**
NGWK	=0; Target Spectrum is a Response Spectrum. Either an Acceleration Spectrum or Psuedo Velocity Spectrum. See **ISPEC** above. =1; Target is Power Spectral Density Function. (**NCYC** is reset to 1)	**I**
IPCH	=0; Accelerogram is **NOT** written to Accelerogram File. Normally used in test runs to see if Spectra generated etc. make sense. =1; Accelerogram is written to Specified File.	**I**

Note: The value of **AGMX** should be slightly larger than the peak acceleration expected for the given Target Spectrum. The peak acceleration value will be scaled to match this value but such an isolated spike in the accelerogram will have minimal effect on the final Spectrum and can be remove manually later. If a too small a values is specified then the whole record will be scaled down so that the peak value matches **AGMX** and the Target Spectrum cannot be matched. In theory it is not realistic to specify both the Peak Acceleration and a Target Response Spectrum. This value is used to control the output if a Power Spectral Density Function is input as the Target.

5. Damping Values.

The **NCYC** damping values are input.

DAMP1 DAMP2 DAMP3 DAMP4 DAMP5

DAMP1	First % Critical Damping Ratio. The input Target Spectrum is assumed to be for this % of Critical Damping and this is used for control of the iteration to match Resultant and Target Spectra.	**F**
DAMP2	Second % Critical Damping Ratio.	**F**
DAMP3	Third % Critical Damping Ratio.	**F**
DAMP4	Fourth % Critical Damping Ratio.	**F**
DAMP5	Fifth % Critical Damping Ratio.	**F**

Note: **DAMP2, DAMP3, DAMP4** and **DAMP5** are only used in the generation of the final Response Spectrum for the accelerogram.

6. **Input Target Spectrum**. One line for each of the **NRES** points.

Either

6a. Response Spectrum. NGWK=0

PERIOD VALUE

PERIOD	Natural Period (Seconds)	**F**
VALUE	Spectral Value (Acceleration or Velocity, see **ISPEC** above)	**F**

Note: The Natural Periods must be in ascending numerical order and the shortest period must be less than or equal **TS** and the longest Period must equal or exceed **TL**
Units for variable **VALUE** are dependant on the type of target spectrum. An Acceleration Spectra is (Gravity) units and a Velocity Spectra is in (length/second) units.

Or

6b. Power Spectral Density Function. NGWK=1

OMEGA VALUE

OMEGA	Circular Frequency (Radians/second)	**F**
VALUE	Power Spectral Density.(Length/second)	**F**

Note: The Natural Frequencies must be in ascending numerical order.

End.