Designation: D5124 – 96 (Reapproved 2022)

Standard Practice for Testing and Use of a Random Number Generator in Lumber and Wood Products Simulation[1]

This standard is issued under the fixed designation D5124; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

1. Scope

1.1 This practice gives a minimum testing procedure of computer generation routines for the standard uniform distribution. Random observations from the standard uniform distribution, R_U, range from zero to one with every value between zero and one having an equal chance of occurrence.

1.2 The tests described in this practice only support the basic use of random number generators, not their use in complex or extremely precise simulations.

1.3 Simulation details for the normal, lognormal, 2-parameter Weibull and 3-parameter Weibull probability distributions are presented.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*See specific warning statement in 5.5.3.

1.5 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

E456 Terminology Relating to Quality and Statistics

3. Terminology

3.1 *Definitions:*

3.1.1 *period*—the number of R_U deviates the computer generates before the sequence is repeated.

3.1.2 *seed value*—a number required to start the computer generation of random numbers. Depending upon the computer system, the seed value is internally provided or it must be user specified. Consult the documentation for the specific random number generator used.

3.1.3 *serial correlation*—the statistical correlation between ordered observations. See 5.2.2.

3.1.4 *standard normal deviate, R_N*—a computer generated random observation from the normal probability distribution having a mean equal to zero and standard deviation equal to one.

3.1.5 *standard uniform deviate, R_U*—a random observation from the *standard uniform distribution.*

3.1.6 *standard uniform distribution*—the probability distribution defined on the interval 0 to 1, with every value between 0 and 1 having an equal chance of occurrence.

3.1.7 *trial*—a computer experiment, and in this standard the generation and statistical test of one set of random numbers.

4. Significance and Use

4.1 Computer simulation is known to be a very powerful analytical tool for both practitioners and researchers in the area of wood products and their applications in structural engineering. Complex structural systems can be analyzed by computer with the computer generating the system components, given the probability distribution of each component. Frequently the components are single boards for which a compatible set of strength and stiffness properties are needed. However, the entire structural simulation process is dependent upon the adequacy of the standard uniform number generator required to generate random observations from prescribed probability distribution functions.

4.2 The technological capabilities and wide availability of microcomputers has encouraged their increased use for simulation studies. Tests of random number generators in commonly available microcomputers have disclosed serious deficiencies (**1**).[3] Adequacy may be a function of intended end-use. This practice is concerned with generation of sets of random

[1] This practice is under the jurisdiction of ASTM Committee D07 on Wood and is the direct responsibility of Subcommittee D07.05 on Wood Assemblies.

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The boldface numbers in parentheses refer to the list of references at the end of this standard.

numbers, as may be required for simulations of large populations of material properties for simulation of complex structures. For more demanding applications, the use of packaged and pretested random number generators is encouraged.

5. Uniformity of Generated Numbers

5.1 *Test of the Mean*—The mean of the standard uniform distribution is ½ . Generate 100 sets of 1000 random uniform numbers and conduct the following statistical test on each set.

$$Z = \frac{\bar{X} - 0.50}{0.009129} \quad (1)$$

where:

Z = test statistic,
$\bar{X}$ = $\sum R_U/1000$,

the standard deviation is assumed to be $\sqrt{\frac{1}{12}}$, and

the summation over 1000 values is implied.

If the absolute value of Z exceeds 1.28 for more than 10 % and less than 30 % of the trials, the random number generator passes. If the random number generator fails the test using 100 sets, then the number of sets can be increased or the random number generator can be rejected.

NOTE 1—The assumption of standard deviation being equal to $\sqrt{\frac{1}{12}}$ may be examined with a Chi-Square test where

$$s = \sqrt{\frac{\left(\sum R_U{}^2 - 1000\,\bar{X}^2\right)}{999}} \quad (2)$$

where:

$\bar{X}$ = estimated mean
s = estimated standard deviation of the 1000 R_U values, and

the summation over 1000 values is implied.

A significant difference between s and $\sqrt{\frac{1}{12}}$, suggests a non-random generator.

5.2 *Test for Patterns in Pairs*—The purpose of this visual test is to evaluate the tendency of pairs of deviates to form patterns when plotted. Generate 2000 pairs of standard uniform deviates. Plot each pair of deviates on an x-y Cartesian coordinate system. Inspect the resulting plot for signs of patterns, such as "strips." Fig. 1 is one example of "stripes" generated by a BASIC function on a personal computer. In more than two dimensions, all generated random numbers fall mainly on parallel hyperplanes, a fact discovered by Marsaglia (**2**).

5.2.1 The following shuffling technique is an effective remedy for the general problem of "stripes" and random numbers falling on planes. Fill a 100-element array with standard uniform deviates. Select a deviate from the array using the integer portion of the product of a random deviate and 100. Replace the selected deviate with a new uniform deviate. Repeat the process until the desired number of deviates has been generated. The plot of Fig. 2 resulted from using the shuffling technique on the random number generator which produced Fig. 1.

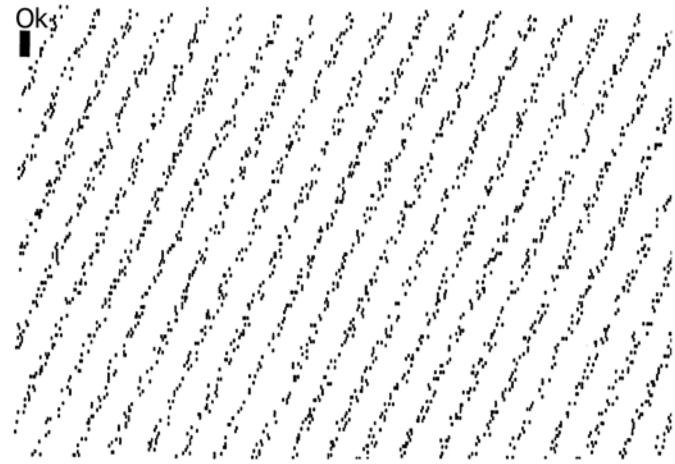
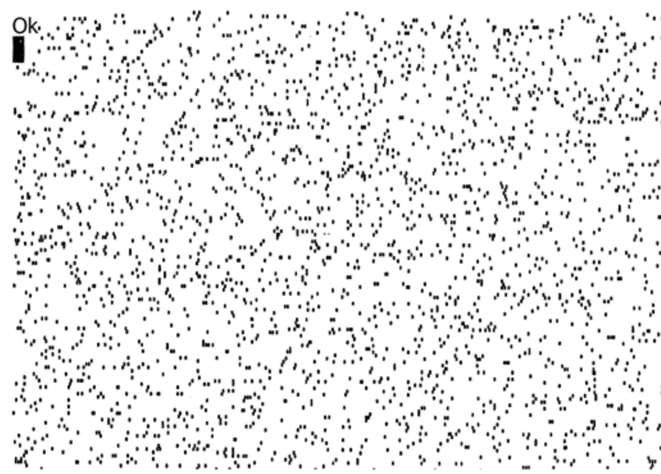


FIG. 1 Plotted Pairs of Random Numbers Showing "Stripes"



NOTE 1—The plot resulted from using the shuffling technique on the generator which produced Fig. 1.

FIG. 2 Plotted Pairs of Random Numbers with no Detectable Patterns

5.2.2 Unless the R_U generator is extensively tested by stringent tests (**3, 4, 5**) a shuffling procedure comparable to that described in 5.2.1 should be used.

5.3 *Visual Test for Uniform Distribution Conformance:*

5.3.1 The purpose of the visual test for distribution conformance is to detect some odd behavior of the random number generator beyond what might be detected by the method in 5.4. It is impossible to predict the various shapes of the histograms which might indicate a problem with the generator. However, a few examples given here may alert the user of the general form of a problem.

5.3.2 *Histogram Preparation*—Fig. 3 is a histogram of 1000 generated standard uniform numbers. The theoretical density function is a horizontal dashed line crossing the ordinate at 1.0. The interval width is 0.1. The values of the ordinates for each interval were calculated as follows:

$$f_i = \frac{N_i}{W_I \times T} \quad (3)$$