FlexMAT™ Asphalt Pavement Analysis Tools Summary and FlexMAT Specified Data Structure for Stress Sweep Rutting Test

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FLEXMAT ASPHALT PAVEMENT ANALYSIS TOOLS

FlexMAT for Cracking is a Microsoft® Excel-based analysis tool for characterizing dynamic modulus and cracking of asphalt pavement mixtures from Asphalt Mixture Performance Tester (AMPT) test results. This includes determining the 2S2P1D dynamic modulus mastercurve coefficients and time-temperature shift factors. It analyzes the AMPT cyclic fatigue test results (AASHTO TP133) to provide inputs to FlexPAVE™ cracking evaluation. These inputs include damage characteristic curve coefficients, failure criteria coefficients, ageing parameters, and the coefficient of thermal contraction. The analysis also supports balanced mix design and production evaluation by calculating the S_{app} index cracking parameter from the test data.

Additional information can be found in the TechBrief, *Cyclic Fatigue Index Parameter (Sapp) for Asphalt Performance Engineered Mixture Design,* 2019. (FHWA-HIF-19-091; https://www.fhwa.dot.gov/pavement/pubs/hif19091.pdf.)

1. "FlexMAT Cracking v2.1.xlsm" (file): Actual FlexMAT v2.1 file, cracking analysis version, ready for testing using the new universal data structure format requirement.

FlexMAT for Rutting is an Excel-based analysis tool for characterizing rutting of asphalt pavement mixtures from AMPT test results. This includes analyzing the AMPT stress sweep rutting (SSR) test results (AASHTO TP134) to provide shift permanent deformation model coefficients to FlexPAVE rutting evaluation. The analysis also supports balanced mix design and production evaluation by calculating the Rutting Strain Index (RSI) parameter from the test data.

Additional information can be found in the TechBrief, *Rutting Strain Index (RSI) Parameter for Asphalt Balanced Mixture Design*, published in 2021. (FHWA-HRT-21-044; https://www.fhwa.dot.gov/publications/research/infrastructure/pavements/21044/index.cfm)

2. "FlexMAT Rutting v2.1.xlsm" (file): Actual FlexMAT v2.1 file, rutting analysis version, ready for testing using the new universal data structure format requirement.

CLIMATIC DATA FILES

Use .csv files with the FlexMAT Rutting v2.1 analysis tool to successfully perform the asphalt pavement rutting analysis. This set of files includes an expanded MERRA2 temperature database from 2,798 locations across the United States, and 20 yr (1996–2015) of temperature information.

3. "Rutting Climate Files.zip" (files): Contains the updated temperature database required for RSI calculations in FlexMAT v2.1 for Rutting.

Extract the .csv files within the .zip file into a folder. If the folder is inside the same overarching folder as the FlexMAT Rutting v2.1 file, it will be automatically identified. If not, the user will be prompted to identify the folder's location.

DATA STRUCTURE REQUIREMENT DOCUMENTS

Use these three documents to understand the AMPT test data and universal format required for FlexMAT to successfully import the test data and conduct the analysis. Each document will show the required data format the equipment manufacturers must use and report from their test equipment. These universal requirements allow the test data to be directly imported into FlexMAT from the equipment. If your equipment is not reporting data in the specified format, use these documents to verify requirements with the manufacturer:

4. "AMPT-DM v1.0_final.docx" (file): Contains the FlexMAT specified data structure for the dynamic modulus test using the AMPT. The test data output must follow the data structure for import to FlexMAT.
5. "AMPT-Fatigue v1.0_final.docx" (file): Contains the FlexMAT specified data structure for the cyclic fatigue test using the AMPT. The test data output must follow the data structure for import to FlexMAT.
6. "AMPT-Rutting v1.0_final.docx" (file): Contains the FlexMAT specified data structure for the stress sweep rutting test using the AMPT. The test data output must follow the data structure for import to FlexMAT.

Upon exporting files from the equipment, users should not open or modify the files using text editors or Microsoft® Excel because such operations may corrupt the files and make them unreadable in FlexMAT.

EXAMPLE TEST DATA REPORT FILES

Use these files as examples of test data output files from the equipment that adhere to the universal data structure requirements to successfully use and analyze the data in FlexMAT.

7. "Input Examples" (folder): Contains dummy examples of Dynamic Modulus, Cyclic Fatigue, and SSR tests in new (universal) formats (compatible with FlexMAT v2.1).

CONTACT

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FLEXMAT SPECIFIED DATA STRUCTURE FOR STRESS SWEEP RUTTING TEST

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GENERAL DATA STRUCTURE ITEMS

- The data files must be in ASCII text format. No specific file extension or file naming convention is required. FlexMAT will browse all the files in selected folder to identify relevant file(s).
- The informational items (those that are not used by FlexMAT) and data (FlexMAT required) are separated by sections. Sections have unique and defined key words enclosed in square brackets ([ ]).
- The comment character is an exclamation point (!).
- Any comments or nondata items within required sections must be preceded by the comment character (!) as the first character in the line. Blank lines are acceptable within any of the sections and will be skipped when reading.
- Section headers are not case-sensitive, but it is recommended to use of upper-case letters for ease of readability and consistency.
- The decimal point or period (".") must be the decimal separator symbol in numeric data fields.
- Within the test data, a comma, space, or tab must be used as field separator. Consecutive field separators (comma and space, for example) will be treated as a single-field separator.
- The positive (+) and negative (–) signs must apply to all loads, actuator displacements, and linear variable differential transformer displacements, and must be shown as:
  - Loads: Compression positive (+), Tension negative (–).
  - Displacements: Extension positive (+), Retraction negative (–).
  - Pressures positive (+), Vacuum negative (–).
- The current version of FlexMAT can accept input of both SI and U.S. units; however, the rutting analysis is based on SI units. SI units should be considered for all data items and units indicated in Section G [UNIT].

RUTTING TEST FILE LOCATION

The program input requires a separate folder for high and low temperatures. Within that folder for each specimen, the program looks for the file with keyword "AMPT-RUT-HT" for high temperature and "AMPT-RUT-LT" for low temperature in the first line.

Note of Caution: If the folder contains any redundant or surplus files with the specified data format, the program uses data from the first set of files read in the calculation. Therefore, the folder must limit the number of files with the specified data format. The number of files in the folder with the specified data format must match the number of specimens indicated in the FlexMAT Worksheet. (Typically, four total specimens are used —two specimens tested at high temperature and two specimens tested at low temperature— with the high and low temperature data placed in two separate folders, respectively.) However, there can be any number of files in other data formats or file types within the folder.

DATA STRUCTURE— RUTTING TEST DATA

ITEM	DATA	DESCRIPTION
A	AMPT-RUT-HT and AMPT-RUT-LT	**A** - Required. First line in the file must have this key word for this data file. FlexMAT browses the files a folder to identify files to read.
B	[VERSION] 1.0	**B** - Required. Must have this section completed and only data item is the version number, currently 1.0, of the file format. Used to track version of file when data format is updated in the future. Not to be confused with FlexMAT version. Any informational item in this section must start with comment character (!).
C	[SUPPLEMENTARY INFORMATION] Project name, device name, device software version, operator, target temperature, or any other test-related information	**C** - Optional. Optional section to document supplementary information. Not required but recommended to include project name, device name, device software version, and operator as a minimum. Can contain any information and not used in the analysis. If available, FlexMAT will read and include it in the report section for reference.
D	[SPECIMEN INFORMATION] Dimensions, conditioning time, properties, or any other specimen-related information	**D** - Optional. Optional section to document specimen information. Can be included or excluded and can contain any information. FlexMAT does not read and skips this section.
E	[SPECIMEN IDENTIFICATION] ! Specimen identification number (maximum 80 characters) ABCDEFG	**E** - Required. Must have this section completed. Only data item is the specimen ID. Any

F [FIELD SEPARATOR]
! 0=comma (","), 1=space (" "), 2=tab
! If comma and space are used together, please select 0 (comma)
! If tab and space are used together, please select 2 (tab)
0

F - Required. Must have this section completed. Only data item is the character type used as the field separator (delimiter) to separate fields (numeric data values) in each input record (line). Any informational item in this section must start with comment character (!).

G [UNIT]
! 0=U.S. Units, 1=SI
! U.S.: Deviator and Contact Stress in psi, Confining Pressure in psi, Temperature in F
! SI: Deviator and Contact Stress in kPa, Confining Pressure in kPa, Temperature in C
1

G - Required. Must have this section completed. Only data item is the unit type used. Must be 0 (U.S. Units - Deviator and Contact Stress in psi, Confining Pressure in psi, Temperature in F) or 1 (SI Units – Deviator and Contact Stress in kPa, Confining Pressure in kPa, Temperature in C). For the selected unit type, the parameters should be reported in the stated magnitude. For example, if SI units is selected, Deviator Stress should be reported in kPa not MPa. Any informational item in this section must start with comment character (!).

H [TEST PARAMETERS]
Temperature, Confining Pressure, Contact Stress, Number of Increment Loading Blocks, Number of Cycles per Increment Loading Block, Load Time per Cycle, Rest Time per Cycle, Rest Time between Increment Loading Block, or any other test parameters.

H - Optional. Optional section to document test parameters. Can be included or excluded and can contain any information. FlexMAT does not read and skips this section.

I [TEST DATA]
Supplemental test data such as Average Deviator Stress, Average Permanent Strain, Average Temperature, Average Confining Pressure, Permanent Deformation, or any other test data.

I - Optional. Optional section to document supplemental test data. Can be included or excluded and can contain any information. FlexMAT does not read but and skips this section.

J [RUTTING TEST DATA]
! Increment Loading Block, Cycle, Deviator Stress, Permanent Strain, Confining Pressure…
1, 1, 672.5, 674, 69.0, 0.8, 40.0, 6.4
1, 2, 690.0, 1062, 69.0, 0.8, 40.0, 6.4
1, 3, 689.5, 1362, 69.0, 0.8, 40.0, 6.5
1, 4, 689.3, 1612, 69.0, 0.8, 40.0, 6.5
….

J - Required. Must have this section completed. Test data in the units specified in the [UNIT] section, one line per cycle within the increment loading block, data items separated by comma, space, or tab, with the following sequence per line: Increment Loading Block, Cycle, Deviator Stress (kPa or psi), Permanent Strain (microstrain), Confining Pressure (kPa or psi), Load Standard Error (%), Temperature (C or F), Contact Stress (kPa or psi). Any informational item in this section must start with comment character (!).