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Template Manual

How to Use Excel–FreET Templates





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IREC Template Manual

1. Introduction

For each problem solved, three documents are available to users: ‘File_name_vyyyy-mm.xls’, an Excel file containing important information about the problem with pre-programmed calculations; FReET file ‘File_name_vyyyy-mm.fre’, a file for calculations based on the stochastic model of input variables; and documentation file ‘File_name_Example_vyyyy-mm.pdf’, a file with a detailed description of the solution to a specific example. With regard to possible further developments and updates to the templates, ‘vyyyy-mm’ in the file name indicates the version of the template, i.e. the year and month of its update.

2. Excel Template Description

The Excel (see e.g. [1]) file template consists of two or more sheets depending on the problem being solved. These are named according to their content, e.g., ‘Moment_resistance’, ‘Deflection’, ‘Literature’, etc.

OUTPUT				
Notation	Variable		Value	Unit
M_R	Moment resistance		54.121	kNm

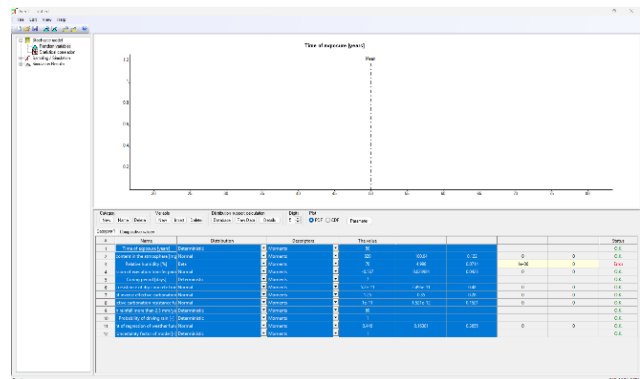
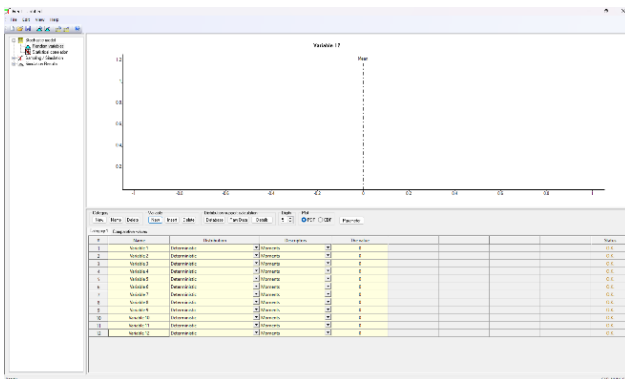
Moment_resistance	Deflection_bending	Deflection_creep	Deflection_shrinkage	Literature	+
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All sheets with pre-prepared calculations have the following structure:

- **Input parameters for the calculation** – to perform a deterministic calculation in Excel, only the numerical values of the input parameters in column A need to be defined; the corresponding rows in columns D, E, and G contain the symbol, description, and unit of the variable in which it is to be defined.
- **Table of ‘INPUT VARIABLES’ definition** – to ensure error-free functionality, do not overwrite the values of the input variables here. These are taken from column A.

- All the ‘SUPPORTING CALCULATIONS’ based on inputs – notation, description, calculated value, unit + equation; the source of literature can be mentioned in P column. For the Excel–FReET interface to work properly, cells containing calculations must not be locked. All calculations are editable by the user. The user is fully responsible for any changes made to the calculation cells.
- **Table of ‘OUTPUT’** – the output calculation + equations and source of literature. For clarity, the output value is located in cell B1 right next to the definition of the input values and is taken from this calculation. For error-free connection to the FReET software, it is necessary that the defined output value is located explicitly in cell B1.
- **Table with the basic ‘STOCHASTIC MODEL’** – statistical definition of input parameters, the source of literature in P column, and other characteristics (such as limits, characteristic and design values etc.) from R columns. Note here, that the area of the stochastic model from columns I to N corresponding to the input parameters (rows 27–48 in the figure) can be copied directly into the .fre file. In such a case, this area must be in a format that meets the requirements of the FReET software (no subscripts/superscripts in column I, distribution type name according to FReET with the first capital letter, ‘Moments’ descriptor for describing inputs using Mean, Std, and COV values). The table area can also be copied to a new .fre file as follows:

Open a new .fre file and prepare the number of rows corresponding to number of inputs → copy the stochastic model from excel sheet → paste it to the cell ‘Name #1’ → check and correct if necessary (e.g. variable limits)



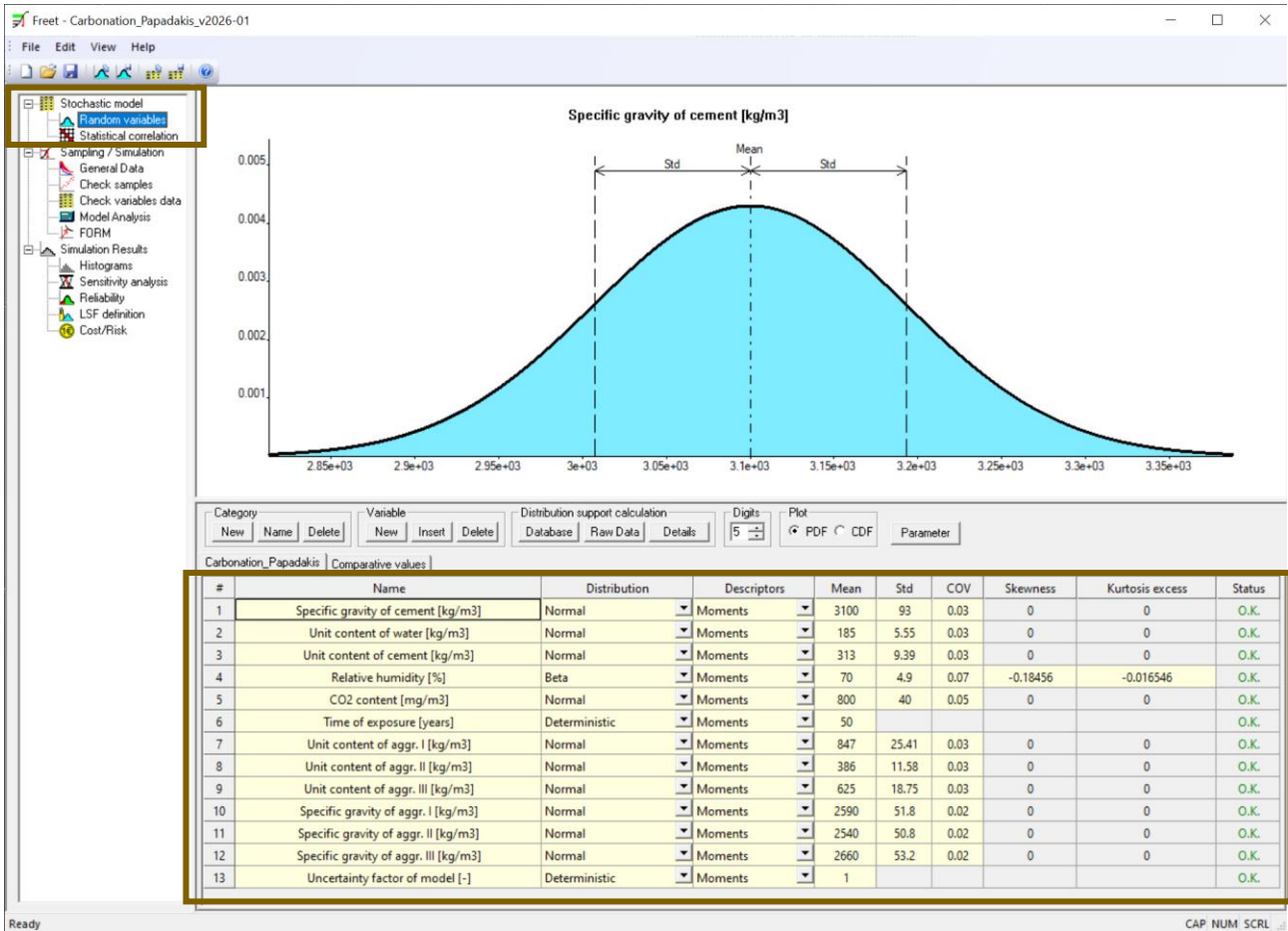
- Information about the ‘SUPPORTING SHEET’ for an individual input – if desired, a supporting sheet with additional information is available for some input variables to make them easier to define.

STOCHASTIC MODEL (define in FReET)						Literature	OTHER CHARACTERISTICS				SUPPORTING SHEET
Name	Distribution	Descriptors	Mean	Std	COV		min	max	X ₁	X _d	
Time of exposure [years]	Deterministic	Moments	50	0	0.0000	[1, 4]	0	1833333			C_CO2
CO2 content in the atmosphere [mg/m3]	Normal	Moments	820	100	0.1220	[1, 4]	0	100			R_ACC-1
Relative humidity [%]	Beta	Moments	70	5	0.0700	[1, 3, 4]	0	100			
Exponent of regression of execution transfer parameter function [-]	Normal	Moments	-0.567	0.023	0.0400	[1, 3, 4]	0	20			
Curing period [days]	Deterministic	Moments	7	0	0.0000	[1, 3, 4]	0	20			
Inverse effective carbonation resistance of dry concrete from ACC-test [(m2/s)/(kg/m3)]	TwoBoundedNormal	Moments	5.20E-11	2.50E-11	0.4800	[1, 3, 4, 6]	1.00E-12	1.00E-09			
Regression parameter of inverse effective carbonation resistance function [-]	Normal	Moments	1.25	0.35	0.2800	[1, 3, 4]					
Error term of inverse effective carbonation resistance function [(m2/s)/(kg/m3)]	Normal	Moments	1.00E-11	1.50E-12	0.1500	[1, 3, 4]					
Days with rainfall more than 2.5 mm/year [days]	Deterministic	Moments	60	0	0.0000	[1, 3, 4]	0	365			
Probability of driving rain [-]	Deterministic	Moments	1	0	0.0000	[1, 3, 4]	0	1			
Exponent of regression of weather function [-]	Normal	Moments	0.446	0.163	0.3660	[1, 3, 4]					
Uncertainty factor of model [-]	Deterministic	Moments	1	0	0.0000	[1, 3, 4, 5]	0				

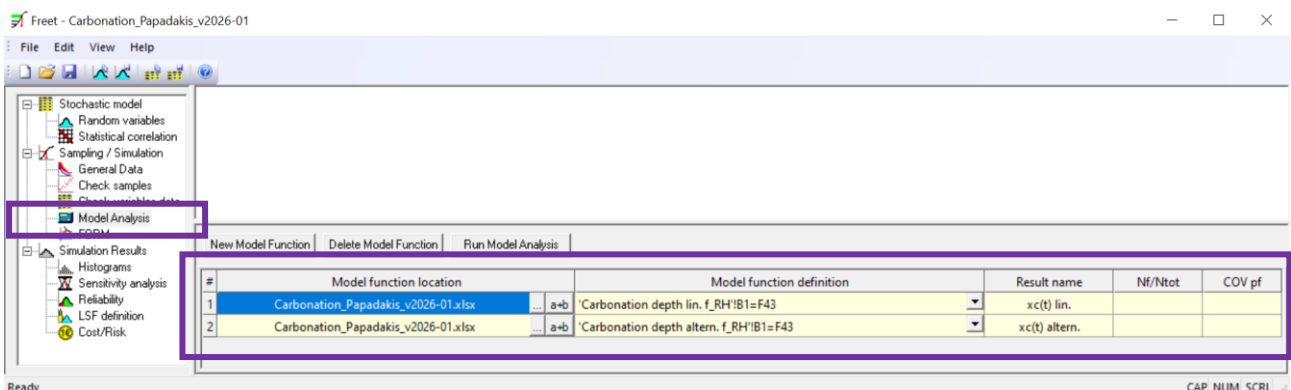
Carbonation dept: C_CO2, R_ACC-1, Literature

3. FReET Template Description

A FReET file template is prepared for immediate use for each individual problem solved. Detailed instructions on how to work with the software are provided in FReET User Manual [2]. An interface between the reliability software FReET and MS Excel is described also in [3]. Each template contains a basic stochastic model with a description of the input variables. This model corresponds to the one provided in the Excel template. The stochastic model can be modified according to user needs.



The correct .xls file required for the calculation is loaded in the Model Analysis section. If the .xls file contains multiple calculation sheets, the corresponding number of analyses is prepared. When working with Excel files, the FReET software is set up to assume that the .fre and .xls templates are stored in the same directory. If there are problems loading the .xls file, the user needs to define the correct path to the file by clicking on the button with three dots. The Model Function definition can be selected by clicking on the triangle button (the link is always to cell B1 of the selected sheet).



4. Example Description

A .pdf file containing a (so far deterministic) solution to a specific example has also been prepared for each template. The documentation consists of a description of the specific problem, a table of input variables, a calculation section, and references. To make the entire calculation process clear to the user, all the relationships used are presented, including numerical substitutions and values obtained on the basis of defined inputs. The user can solve and check such an example by simply entering numerical values of inputs into the .xls template (column A as mentioned in section 2).

1. Introduction

The complex model of concrete carbonation is based on [1] and calculates the depth of the carbonation front x_c at time t . In this example, a prediction of the carbonation depth x_c is made for a newly concreted slab bridge after a period of 10 years of operation. A concrete mix with CEM I 45.5 R with a water-to-cement ratio $w/c = 0.55$ was used, with a curing time of 14 days. The bridge is located in an environment with a normal CO_2 concentration (420 ppm). Based on meteorological data for the location, the average temperature of ambient air $T = 12^\circ\text{C}$, relative humidity $\text{RH} = 75\%$ and 55 rainy days per year were measured at the time of the construction of the bridge.

2. Input variables

Notation	Variable	Value	Unit
t	Time of exposure	10	years
C_{CO_2}	CO_2 content in the atmosphere	789.83	mg/m^3
RH	Relative humidity	75.00	%
k_c	Exponent of regression of execution transfer parameter function	-0.567	-
t_c	Curing period	14	days
R_{ACC}^{-1}	Inverse effective carbonation resistance of dry concrete from ACC-test	$9.80 \cdot 10^{-11}$	$(\text{m}^2/\text{s})/(\text{kg}/\text{m}^3)$
k	Regression parameter of inverse effective carbonation resistance function	1.25	-
q	Error term of inverse effective carbonation resistance function	$1.00 \cdot 10^{-11}$	$(\text{m}^2/\text{s})/(\text{kg}/\text{m}^3)$
f_w	Days with rainfall more than 2.5 mm/day	55	days
p_{DR}	Probability of driving rain	1.00	-
θ_w	Exponent of regression of weather function	0.446	-
θ	Uncertainty factor of model	1.00	-

3. Deterministic Calculation and Comments

The CO_2 content on the atmosphere is set in parts per million by volume (ppm). In the model it is needed to be in mg/m^3 . For the conversion following relation can be used with $M_{\text{CO}_2} = 44 \text{ g/mol}$, $p = 101.325 \text{ Pa}$, $R = 8.314 \text{ J}/(\text{mol}\cdot\text{K})$ and T the temperature of structural elements or ambient air in K:

$$C_{\text{CO}_2} [\text{mg}/\text{m}^3] = M_{\text{CO}_2} \cdot 10^3 \frac{p}{RT} C_{\text{CO}_2} [\text{ppm}] \cdot 10^{-6} = 44 \cdot 10^3 \frac{101325}{8.314 \cdot (12 + 273.15)} \cdot 420 \cdot 10^{-6} = 789.83 \text{ mg}/\text{m}^3$$

For easier conversion see the 'C CO₂' sheet in the Excel template file, where the temperature in °C is defined as an input parameter and the CO_2 concentration is calculated in mg/m^3 for the range of values in ppm.

The execution transfer parameter k_c takes into account the influence of curing defined by the number of curing days t_c on effective carbonation resistance with recommended value $k_c = -0.567$:

$$k_c = \left(\frac{t_c}{7}\right)^{0.5} = \left(\frac{14}{7}\right)^{0.5} = 0.675$$

The inverse effective carbonation resistance R_{ACC}^{-1} is to be determined by accelerated carbonation tests (ACC test method). If no test data is available, the literature-derived data can be used for orientation purposes; see also the 'R ACC-1' sheet in the Excel template file. The factors k and q have been introduced in order to transform the results gained under the accelerated carbonation

$$R_{\text{ACC}}^{-1} = k_c \cdot R_{\text{ACC}}^{-1} + \epsilon_1 = 1.25 \cdot 9.80 \cdot 10^{-11} + 1.00 \cdot 10^{-11} = 13.25 \cdot 10^{-11} \frac{\text{m}^2/\text{s}}{\text{kg}/\text{m}^3}$$

Time of wetness is the number of rainy days f_w per year (days with rainfall more than 2.5 mm/day):

$$T_oW = \frac{f_w}{365} = \frac{55}{365} = 0.151 \text{ years}$$

The environmental function k_e considers the influence of relative humidity RH on the carbonation resistance of the concrete and is calculated as (with $R_{\text{H,ref}} = 65\%$):

$$k_e = \left(\frac{1 - (\text{RH}/100)^2}{1 - (\text{RH}_{\text{ref}}/100)^2}\right)^{0.5} = \left(\frac{1 - (75/100)^2}{1 - (65/100)^2}\right)^{0.5} = 0.691$$

The exponent of weather function w is calculated as follows with the recommended value of the exponent $\theta_w = 0.446$:

$$w = \frac{(p_{\text{DR}} \cdot T_oW)^{\theta_w}}{2} = \frac{(1.00 \cdot 0.151)^{0.446}}{2} = 0.215$$

Parameters p_{DR} and T_oW take into account the rain events. A probability of driving rain p_{DR} is a constant parameter of the average distribution of the wind direction during rain events which is carried out by determining the wind direction during rain events, based on data from the nearest weather station. For interior structural elements $p_{\text{DR}} = 0$ and for horizontal elements subjected to rain events $p_{\text{DR}} = 1$.

The weather function $W(t)$ for a reference time t_0 is calculated as:

$$t_0 = \frac{28}{365} = 0.0767 \text{ years}$$

$$W(t) = \left(\frac{t_0}{t}\right)^w = \left(\frac{0.0767}{10}\right)^{0.215} = 0.351$$

The carbonation rate is calculated according to following formula with $R_{\text{ACC},0}^{-1}$ being converted into $(\text{mm}^2/\text{year})/(\text{kg}/\text{m}^3)$:

$$A = \sqrt{2 \cdot 315.5 \cdot 10^{11} \cdot k_e \cdot k_c \cdot R_{\text{ACC}}^{-1} \cdot C_{\text{CO}_2} \cdot 10^{-6}} \\ = \sqrt{2 \cdot 315.5 \cdot 10^{11} \cdot 0.691 \cdot 0.675 \cdot 13.25 \cdot 10^{-11} \cdot 789.83 \cdot 10^{-6}} = 1.76 \text{ mm}/\text{year}^{0.5}$$

Finally, including the model uncertainty factor θ (recommended value $\theta = 1$), the carbonation depth x_c in time t is calculated based on the formula:

$$x_c(t) = \theta \cdot A \cdot \sqrt{t} \cdot W(t) = 1.00 \cdot 1.76 \cdot \sqrt{10} \cdot 0.351 = 1.95 \text{ mm}$$

4. Literature

[1] fib – International Federation for Structural Concrete (2006) fib Bulletin 34: Model Code for Service Life Design. Lausanne, Switzerland.

In the future, it is planned to extend the documentation with stochastic calculations and all necessary information and sources. The .xls and .fre templates can also be updated based on user requests and feedback. This will be reflected by indicating the file version in its name (in the form of the year and month of the update 'yyyy-mm').

5. References

- [1] <https://www.microsoft.com/en-us/microsoft-365/excel>
- [2] Novák, D., Rusina, R., Vořechovský, M. (2006) FReET Program Documentation – Part 2 – User Manual. Brno/Červenka Consulting, Prague, Czech Republic. <http://www.freet.cz/>
- [3] Novák, D., Vořechovský, M., Rusina, R. (2025) Making reliability analysis easy using MS Excel and FReET software. Procedia Structural Integrity, Vol. 73, pp. 119–124.