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SINTEF REPORT

TITLE

CARE-S WP2 External corrosion model description

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ABSTRACT

Under the CARE-S project, Computer Aided Rehabilitation of Sewer Networks, the structural condition of sewer pipes is determined and their future condition calculated. Several probabilistic, empirical and deterministic tools are included to define current and future condition. The empirical-deterministic approach includes the assessment of external and internal corrosion depths and the resulting strength of the sewer pipe. The tool for assessing the external corrosion is described in this report.

ExtCorr is a computer program that empirically estimates external corrosion for concrete pipes, depending on their environmental conditions. A risk factor model with a linear external corrosion has been developed. The tool is kept very basic in order to avoid extensive data mining and sample taking. It gives an educated estimation of external corrosion quantities while keeping the data demand to a minimum at the same time.

The linear corrosion is dependent on soil aggressiveness, soil moisture and the cement quality of the concrete pipe. Those factors are defined in a matrix that can be adapted by the user.

This report contains a mathematical description of the tool, its strengths and limitations and a user guideline to run the tool.

KEYWORDS	ENGLISH	NORWEGIAN
GROUP 1	concrete pipe	sementledning
GROUP 2	external corrosion	eksternt korrosjon
SELECTED BY AUTHOR	soil aggressiveness	jord aggressivitet

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User guide for the External corrosion model under CARE-S

Tool version number: 1.0.2

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1 General description

ExtCorr is a computer program that empirically estimates external corrosion for concrete pipes, depending on their environmental conditions. A risk factor model with a linear external corrosion has been developed. The tool is kept very basic in order to avoid extensive data mining and sample taking. It gives an educated estimation of external corrosion quantities while keeping the data demand to a minimum at the same time.

The tool is published either as a stand-alone program or as an integrated facility within the CARE-S software package.

2 Scope of application

The functionality of ExtCorr has to be seen in the context of the calculation of structural condition in CARE-S, together with the internal corrosion models (WATS and Z-model) and the Load_model. The latter depends on the input of external and internal corrosion depth in order to calculate the security against structural collapse. WATS delivers the internal corrosion in millimetre per year with a detailed deterministic model. ExtCorr delivers the total external corrosion in millimetre with an empirical model. While ExtCorr gives a rough estimation of the magnitude of external corrosion, WATS is very detailed, including a hydraulic module. With a high input data demand, WATS will probably be applied for some chosen areas and transferred to the network. ExtCorr can be applied for all pipes in a network at once. The user chooses the scale of areas with similar soil aggressiveness.

3 Strengths and limitations

The tool is designed to give a rough estimation for the magnitude of external corrosion on sewer concrete pipes. The external conditions are hardly known to a degree where the modelling of a deterministic model can be justified. The chosen approach is therefore adequate to the expected data situation. A risk factor model with a linear external corrosion has therefore been developed for this approach. It can be applied to the sewer network without any information on the assets besides pipe ID and installation year. In this case it serves as a tool for sensitivity analysis.

Two input parameter that can be transferred from the CARE-S Manager are directed at the environmental conditions that can lead to external corrosion. One is on information about soil moisture and the other on information about soil aggressiveness. Soil moisture is obtained from installation depth and ground water level. This data will hardly be imported together with the asset database and can therefore be edited under the CARE-S Manager. For batch editing, the user can choose existing zones or draw polygons around areas with similar environmental conditions.

Additionally to soil and moisture conditions, the cement quality of the concrete pipe plays a role for the resistance against chemical corrosion. A low water-cement ratio will have a greater

resistance. The cement quality has improved over time and the user has the possibility to choose three installation periods to reflect this.

The tool contains also a switch function for the installation year from when on good drainage material has been used as filling material instead of surrounding soil. Pipes under that condition are placed under non-corrosive soil type.

The ExtCorr model is in summary a very flexible tool with many adjusting possibilities. All parameters can be edited. The tool is well suited for a sensitivity analysis and should be applied by advanced users who understand quality and uncertainty of in- and output data.

4 Mathematical description

Three factors affect the external corrosion of concrete sewer pipes, soil moisture around the pipe, soil aggressiveness and resistance of the cement type. Pipe surrounded by ground conditions that are acidic or contain carbon dioxide are in general exposed to corrosion. Acids that react with the cement at the concrete surface usually form a kind of soft paste and aggressive carbon dioxide dissolves the hydrated cement. A high soil moisture generally accelerates this process while a low water-cement ratio of the concrete pipe increases the resistance.

Soil aggressiveness applies mostly to older pipes. Filling material from the surrounding soil has been used up to a certain time (in Norway around 1970). Today, this factor can be neglected because of a better drainage in the trench of new installations and the use of sulphate resistant cement.

Soil aggressiveness is divided into 3 grades of risk for external deterioration in the ExtCorr model: Grade 0 for no risk (drainage filling material), grade 1 for filling material containing ammonium and nitrate and grade 2 for material containing sulphate.

Soil moisture is derived from the difference between ground water and pipe depth. Ground water level is defined as depth of ground water below surface to avoid topographical information. Soil moisture equally been divided into 3 grades: Grade 0 for dry conditions (pipe is at least 0,5 meter above ground water level), grade 1 for medium conditions (pipe is just above ground water level, 0-0,5 meter above) and grade 3 for wet conditions (pipe is permanently submersed, pipe depth is greater than ground water level).

The external corrosion is based on the following equation:

$$(1) \quad C_{\text{ext}} = a * b (\text{year}_{\text{pred}} - \text{year}_{\text{inst}})$$

With C_{ext} : total external corrosion [mm]

a : external corrosion coefficient [mm/year]

b : pipe quality coefficient (water cement ratio)

$\text{year}_{\text{pred}}$: The prediction year for the calculation (year of rehabilitation planning)

$\text{year}_{\text{inst}}$: The installation year of the pipe

The coefficient a is chosen from a matrix based on the above described moisture grade and soil type. Three different grades of each result in a total of 9 values. The default values in table 1 are based on statistical analysis of sewer concrete pipe samples taken in Norway at different locations. All values can be adapted by the user.

Table 1: Soil moisture – soil aggressiveness matrix for parameter a

Soil moisture	Soil aggressiveness		
	non corrosive	medium corrosive	high corrosive
dry	0,01	0,1	0,3
medium	0,05	0,2	0,5
wet	0,1	0,5	0,7

The coefficient b is based on the cement resistance grade. It can be chosen between three bands of water-cement ratios. Each band is related to a period of pipe installation. Suggestions for Norwegian conditions are provided as default values, see table 2. The b -values and the bands of installation year can be changed by the user.

Table 2: Cement resistance table for parameter b

Resistance grade	good	medium	poor
Water-cement ratio	< 0,3	< 0,45	\geq 0,45
b	1,0	1,5	2,0
Installation year	\geq 1976	1961 - 1975	\leq 1960

5 Data demand

An extensive set of data is imported into the ExtCorr model from the CARE-S manager. This file is a text file with the following parameters:

PipeName=	<pipe identification>	any pipe identification
Shape=	<circular>	all pipes assumed to be circular
Width=	<pipe width [mm]>	diameter, currently not used
Height=	<pipe height [mm]>	for non-circular pipes, currently not used
Year=	<installation year>	construction year, when the pipe is laid
Length=	<pipe length [m]>	pipe length, currently not used
WallThick=	<pipe wall thickness [mm]>	currently not used
Depth=	<pipe depth [m]>	used for calculation of soil moisture
SDR=	<standard dimension ratio>	currently not used
PN=	<pressure class>	currently not used
Mat=	<pipe material>	all pipes assumed to be concrete
Soil=	<soil class>	valid values: non, med, high
GW=	<ground water level [m]>	meter below surface

Many parameters from the input file are currently not used and will not affect the tool and its results when they are empty. The excessive data fields origin from previous tool concepts or are included to increase the functionality of the tool in later versions.

The **minimum data demand** in version 1.0.2 is:

PipeName=	<pipe identification>	any pipe identification
Year=	<installation year>	construction year, when the pipe is laid
Depth=	<pipe depth [m]>	used for calculation of soil moisture

Soil= <soil type> valid values: non, med, high
GW= <ground water level [m]> meter below surface

In case of missing data for pipe depth, soil type and ground water level, the user is recommended to fill those data fields in the CARE-S Manager by batch editing under the GIS functionality. Alternatively, in case of missing soil type, the user can apply a switch function in the ExtCorr tool. He can edit a specific year from when on draining material is used as filling material. Before this year, the soil receives a medium corrosiveness and after that year it is non-corrosive.

6 Output data

The output from the ExtCorr model is the total external corrosion for a pipe in millimetre. The user has several possibilities to export the output data: saving to the CARE-S Manager database, exporting to an MS Excel File or listing in a tabular form.

Example of output file:

```
***  
PipeName=1  
ExCor= 0.24  
  
***  
PipeName=2  
ExCor= 1.33  
  
***  
PipeName=3  
ExCor= 2.06
```

7 How-to guide

The ExtCorr model is developed independently from the CARE-S Rehab Manager and can therefore also be used as a stand alone version. In that case, the user starts directly with step 2.

- Step 1.1 Select a set of pipes, using the GIS viewer facility and/or Expression Builder of the Rehab Manager. This active dataset will be analysed using the ExtCorr model for the prediction year chosen by the user.
- Step 1.2 From the tools menu in the Rehab Manager select ExtCorr tool. The user has the option to select the calculating year. A pre-defined data set is transferred from the Manager to the tool for the chosen pipes.
- Step 1.3 Once the relevant auto-load has been completed, select run 'ExtCorr tool' from the External corrosion menu option. The tool will then be started and the opening page is shown (figure 1) for a few seconds before the tool switches over to the main page (figure 2). Continue with step 3 if the tool is run from the Rehab Manager

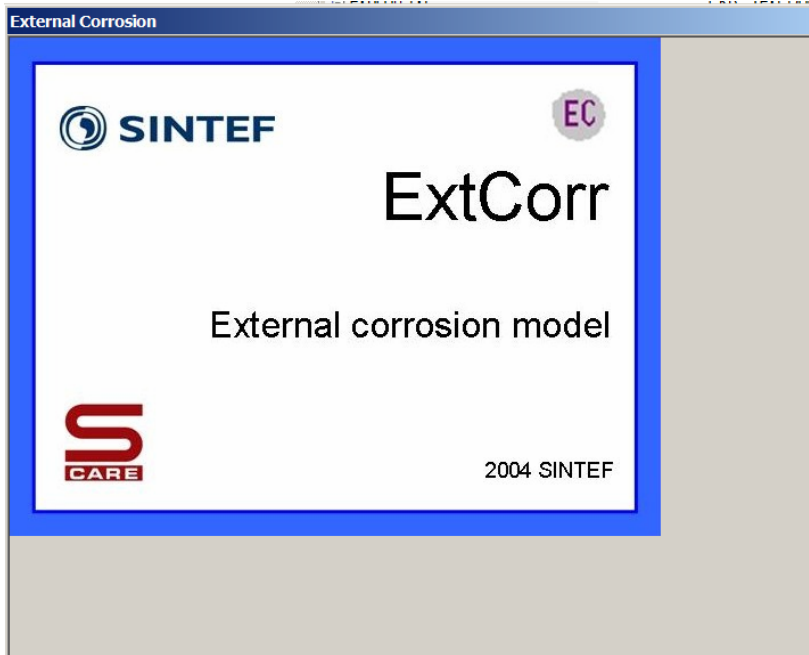


Figure 1: Opening page of the Load_model

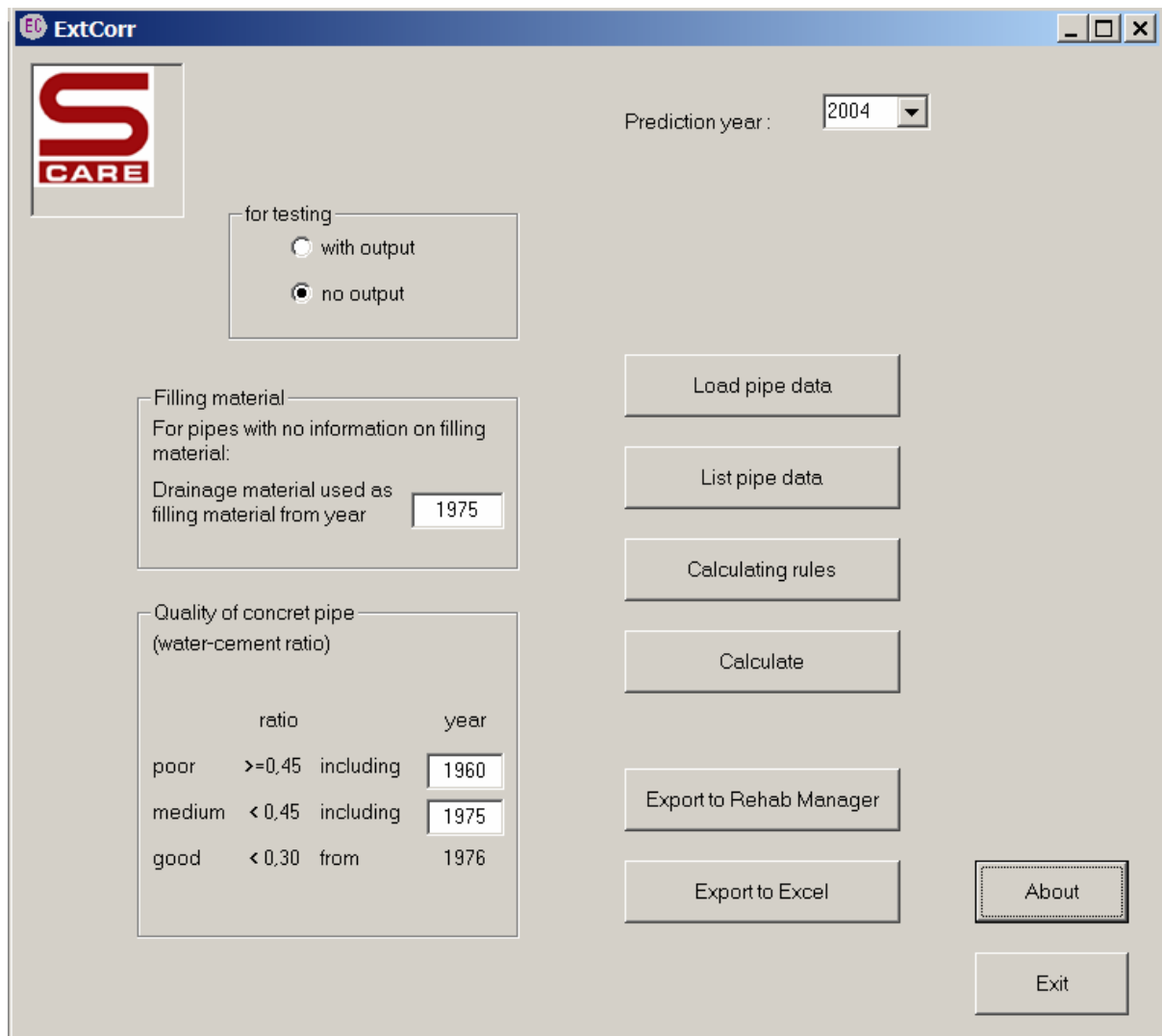
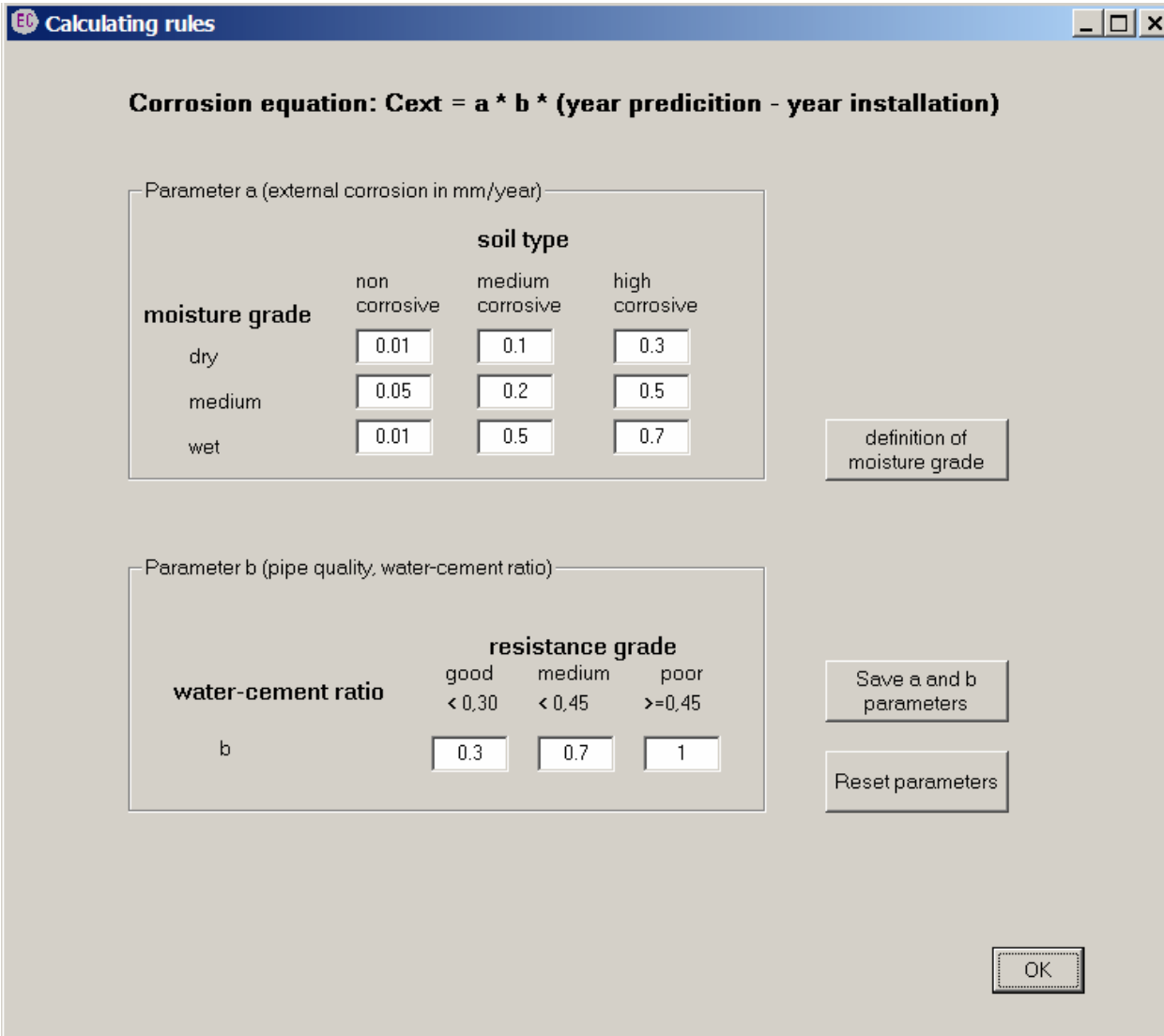


Figure 2: Main screen picture

- Step 2.1 Start ExtCorr model with the execute file. The tool will then be started and the opening page is shown (figure 1) for a few seconds before the tool switches over to the main page (figure 2).
- Step 2.2 Select calculating year for which the rehabilitation planning will be done.
- Step 2.3 Load pipe data from a pre-processed text file according data input specification.
- Step 3.1 Look at the pipe data by selecting List pipe data. Empty fields mean that there was no data transferred from the Rehab Manager. 'N/A' is shown in result fields before calculation is done. Note that you can change the view by adding or deleting columns in this list and sorting the list for any parameter.
- Step 3.2 Verify suggested values for soil information or water cement ratio and edit if necessary.



Calculating rules

Corrosion equation: $C_{ext} = a * b * (\text{year prediction} - \text{year installation})$

Parameter a (external corrosion in mm/year)

moisture grade	soil type		
	non corrosive	medium corrosive	high corrosive
dry	0.01	0.1	0.3
medium	0.05	0.2	0.5
wet	0.01	0.5	0.7

definition of moisture grade

Parameter b (pipe quality, water-cement ratio)

water-cement ratio	resistance grade		
	good < 0,30	medium < 0,45	poor >=0,45
b	0.3	0.7	1

Save a and b parameters

Reset parameters

OK

Figure 3: Calculating rules in ExtCorr model

- Step 3.3 Go further to ‘calculating rules’, verify and maybe change a and b parameter values that define the corrosion speed (figure 3). Save the parameter values if you want to keep them for future calculations. Press ‘OK’ and go back to the main menu.
- Step 3.4 Run the calculations for the chosen set of pipes.
- Step 3.5 Look at the results through List pipe data.
- Step 3.6 Export the result data to CARE-S Rehab Manager and/or an Excel spreadsheet.