Software Requirements Specification for : Concrete Remaining Life Prediction

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Contents

Revision History

Date	Version	Notes
February 5	1.0	Initial Documentation

1 Reference Material

This section records information for easy reference.

1.1 Table of Units

Throughout this document SI (Système International d'Unités) is employed as the unit system. In addition to the basic units, several derived units are used as described below. For each unit, the symbol is given followed by a description of the unit and the SI name.

symbol	**unit**	**SI**
m	length	metre
s	time	second
°C	temperature	centigrade
A	electric current	ampere
µ	micro	10^{-6}

1.2 Table of Symbols

The table that follows summarizes the symbols used in this document along with their units. The choice of symbols was made to be consistent with the heat transfer literature and with existing documentation for solar water heating systems. The symbols are listed in alphabetical order.

symbol	**unit**	**description**
A_{cr}	μA/cm^2	Average corrosion rate of a year
A_d	mm	Accumulated deterioration at time t_y
A_{df}	mm	Amount of damage at failure
C_1	-	Coefficient weighing the impact of corrosion rates (Icorr) in M_1
C_2	-	Coefficient weighing the impact of corrosion rates (Icorr) in M_2
C_3	-	Coefficient weighing the impact of corrosion rates (Icorr) in M_3
H_r	%	Relative humidity
I_{corr}	-	Corrosion Rates (Icorr)
k_d	mm/year	Factors influencing deterioration at time t_y
M_1	month	Number of months that relative humidity is below 70%
M_2	month	Number of months that relative humidity is between 70 and 100%
M_3	month	Number of months that rain occurs
n	year	Time order

R_d	m/s	Rate of concrete degradation
t_i	year	Age of the concrete at the time of condition inspection
t_r	year	Remaining service life of concrete
t_y	year	Service life of concrete
t_f	year	Time to failure

1.3 Abbreviations and Acronyms

symbol	description
A	Assumption
DD	Data Definition
GD	General Definition
GS	Goal Statement
Icorr	Corrosion rates
IM	Instance Model
LC	Likely Change
PS	Physical System Description
R	Requirement
RH	Relative humidity
SRS	Software Requirements Specification
TM	Theoretical Model
UI	User Interface

2 Introduction

In response to the critical need for predicting the remaining life of concrete structures, this project aims to develop a program that implements theories introduced by a United States laboratory in 1992. Their work emphasized the importance of estimating remaining service life to enable property owners to plan for repairs or demolitions proactively. The program's goal is to predict the remaining service life of concrete structures, offering a valuable tool for effective maintenance and decision-making.

The upcoming section will present a roadmap for the Software Requirements Specification (SRS) of the program. This segment elucidates the document's purpose, outlines the scope of the requirements, and describes the characteristics of the target audience for this document.

2.1 Purpose of Document

The primary aim of this document is to outline the requirements of the Concrete Remaining Life Prediction program. This encompasses background information, goals, assumptions, theoretical models, definitions, and other details related to model derivation. These components collectively enable the audience to gain a clear understanding and verify the purpose and scientific basis of this program.

2.2 Scope of Requirements

This document explores the impact of climate data and the level of concrete deterioration on concrete structures, with the aim of implementing a predictive program.

2.3 Characteristics of Intended Reader

The intended Reviewers of this documentation should possess an understanding of meteorology or building environments. Additionally, a basic grasp of high-school level mathematics and chemistry is recommended. For users of the prediction program can have a lower level of expertise, as further explained in the "User Characteristics" section (Section 3.2).

2.4 Organization of Document

The organization of this document follows the SRS template provided by Dr. Smith and the GlassBR SRS document.

3 General System Description

This section provides general information about the system. It identifies the interfaces between the system and its environment, describes the user characteristics and lists the system constraints.

3.1 System Context

Figure 1 illustrates the system context. In this representation, a circle signifies an external entity, which, in this case, is the user. The rectangle represents the prediction program, and arrows depict the data flow between the system and its environment.

The interaction between the product and the user is through a UI. The responsibilities of the user and the system are as follows:

- User Responsibilities: Provide the input data related to climate and concrete deterioration level, ensuring that the entry data is valid.
- Prediction Program Responsibilities: Determine if the inputs satisfy the required program constraints and predict the remaining service life of concrete.

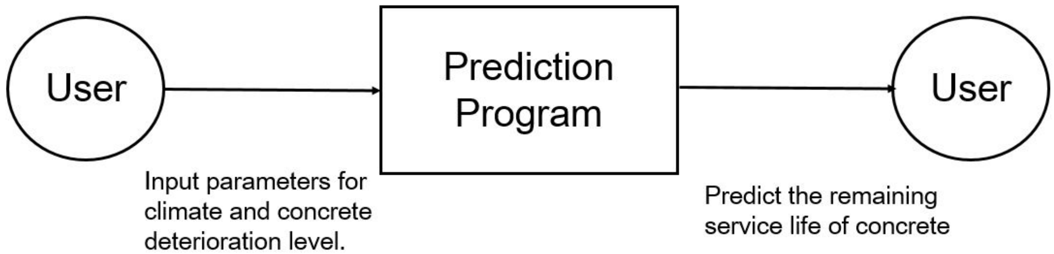

Figure 1: System Context

3.2 User Characteristics

- The end user is expected to possess basic computer literacy for effectively handling the software.
- The end user is expected to have an understanding of the theory behind concrete degradation measurement and its root causes.

3.3 System Constraints

There are no system constraints.

4 Specific System Description

This section first presents the problem description, which gives a high-level view of the problem to be solved. This is followed by the solution characteristics specification, which presents the assumptions, theories, definitions and finally the instance models.

4.1 Problem Description

A system is required to predict the remaining service life of concrete by integrating climate data and concrete degradation levels.

4.1.1 Terminology and Definitions

This subsection provides a list of terms that are used in the subsequent sections and their meaning, with the purpose of reducing ambiguity and making it easier to correctly understand the requirements:

1. Corrosion rates (Icorr): The flow of electric charge associated with the corrosion reactions occurring on a metal surface.

2. Deterioration Factors:
    - Carbonation
    - Diffusion of chloride ions
    - Acid attack (siliceous aggregate)
    - Acid attack (carbonate aggregate)
    - Sulfate attack
    - Frost attack
    - Active corrosion of steel
    - Reinforcement (propagation)
3. Rain: Precipitation in the form of liquid water droplets greater than 0.5 mm. If widely scattered, the drop size may be smaller.
4. Relative Humidity: Relative humidity in percent (%) is the ratio of the quantity of water vapour the air contains compared to the maximum amount it can hold at that particular temperature.

4.1.2 Physical System Description

The physical system regarding how deterioration occurs is not discussed in this study.

4.1.3 Goal Statements

Develop a prediction program that implements the theories, with the goal of predicting the remaining service life of concrete structures.

4.2 Solution Characteristics Specification

The instance models that govern this program are presented in Subsection 4.2.5. The information to understand the meaning of the instance models and their derivation is also presented, so that the instance models can be verified.

4.2.1 Assumptions

This section simplifies the original problem and helps in developing the theoretical model by filling in the missing information for the physical system. The numbers given in the square brackets refer to the theoretical model [TM], general definition [GD], data definition [DD], instance model [IM], or likely change [LC], in which the respective assumption is used.

A1: The values of k_d remain constant throughout the entire deterioration period.
A2: The factors influencing the remaining life of concrete and causing degradation are restricted to the following: carbonation, diffusion of chloride ions, acid attack (siliceous aggregate), acid attack (carbonate aggregate), sulfate attack, frost attack, active corrosion of steel and reinforcement (propagation).
A3: Disregard self-conditions of concrete, such as cover thickness.
A4: Unless specifically mentioned, consider multiple degradation processes occurring simultaneously, making the time order n=1.
A5: If only one degradation process occurs, implicitly refer to Table 1 to determine the exact value of n.
A6: All information obtained from inspections is accurate.
A7: Relative humidity is the only factor that influences Icorr.
A8: Distribute based on M_1 , M_2 and M_3 three periods.
A9: The relative humidity value needs to remain consistently below 70% for a month to be considered in the calculation of the M1 value. The same applies to the M_2 and M_3 values.
A10: The relationship between M1 and M_2 is mutually exclusive to M_3. In other words, there is no rain during the M_1 and M_2 periods.

4.2.2 Theoretical Models

This section focuses on the general equations and laws that this program is based on.

Number	TM1
Label	**Remaining service life**
Equation	t_r=t_f-t_i
Description	t_{yf} is time to failure. t_i is the age of the concrete at the time of condition inspection. t_r is the remaining service life of the concrete. The above equation calculate the remaining service life.
Sources	-
Ref. By	-

Number	TM2
Label	**Average corrosion rate of a year**
Equation	$$A_{cr} = \frac{C_1 \cdot M_1 + C_2 \cdot M_2 + C_3 \cdot M_3}{12}$$
Description	C_1 is Coefficient weighing the impact of corrosion rates (Icorr) in M_1. C_2 is Coefficient weighing the impact of corrosion rates (Icorr) in M_2. C_3 is Coefficient weighing the impact of corrosion rates (Icorr) in M_3. M_1 is Number of months that relative humidity is below 70%. M_2 is Number of months that relative humidity is between 70 and 100%. M_3 is Number of months that rain occurs. The above equation calculates average corrosion rate of a year.
Sources	-
Ref. By	-

4.2.3 General Definitions

There are no general definitions.

4.2.4 Data Definitions

This section collects and defines all the data needed to build the instance models. The dimension of each quantity is also given.

Number	DD1
Label	**Month data**
Symbol	M
SI Units	months
Equation	$M = M_1 + M_2 + M_3$
Description	M represents the weather data for 12 months. Specifically, M1 denotes the number of months with relative humidity below 70%, M2 indicates the number of months with relative humidity between 70 and 100%, and M3 represents the number of months with rainfall.
Sources	Methods for Predicting Remaining Life of Concrete in Structures
Ref. By	TM2

Number	DD2
Label	Coefficient weighing the impact of corrosion rates (Icorr) in M
Symbol	M_1, M_2, M_3, C_1, C_2, C_3
SI Units	-
Equation	$\begin{cases} M_1, C_1 = 0.1 \\ M_2, C_2 = 1.0 \\ M_3, C_3 = 10 \end{cases}$
Description	The coefficient for M_1 will be 0.1, for M_2 it will be 1.0, and for M_3 it will be 10.
Sources	Methods for Predicting Remaining Life of Concrete in Structures
Ref. By	TM2

4.2.5 Instance Models

This section transforms the problem defined in Section 4.1 into one which is expressed in mathematical terms. It uses concrete symbols defined in Section 4.2.4 to replace the abstract symbols in the models identified in Sections 4.2.2 and 4.2.3.

Number	IM1
Label	**Amount of concrete degradation**
Input	k_d, t_y, n
Output	A_d
Description	A_d is Accumulated deterioration at time t_y. k_d is Factors influencing deterioration. t_y is Service life of concrete. n is time order The above equation calculate the amount of concrete degradation.
Sources	-
Ref. By	TM1

Number	IM2
Label	**Rate of concrete degradation**
Input	n, k_d, t_y, n-1
Output	R_d
Description	R_d is rate of degradation. k_d is factors influencing deterioration. t_y is service life of concrete. n is time order The above equation calculate the rate of degradation.
Sources	-
Ref. By	TM1

Number	IM3
Label	**Calculate the time to get failure**
Input	A_{df}, k_d, $1/n$
Output	t_{yf}
Description	A_{df} is the amount of damage at failure. k_d is the factor influencing deterioration. t_{yf} is the time to failure.
	n is time order The above equation calculate the time to get failure.
Sources	-
Ref. By	TM1

4.2.6 Input Data Constraints

Table 1 shows the data constraints on the input output variables. The column for physical constraints gives the physical limitations on the range of values that can be taken by the variable. The column for software constraints restricts the range of inputs to reasonable values. The software constraints will be helpful in the design stage for picking suitable algorithms. The constraints are conservative, to give the user of the model the flexibility to experiment with unusual situations. The column of typical values is intended to provide a feel for a common scenario. The uncertainty column provides an estimate of the confidence with which the physical quantities can be measured. This information would be part of the input if one were performing an uncertainty quantification exercise.

Table 1: Input Variables

Var	**Physical Constraints**	**Software Constraints**	**Typical Value**	**Uncertainty**
t_y	$t_y \geq 0$	–	1 year	10%
n	$n \geq 0$	–	1	10%
A_{df}	$A_{df} \geq 0$	–	10mm	10% M_1
$12 \geq M_1 \geq 0$	–	4months	10%	
M_2	$12 \geq M_1 \geq 0$	–	4months	10%
M_3	$12 \geq M_1 \geq 0$	–	4months	10%

4.2.7 Properties of a Correct Solution

A correct solution must exhibit fill in the details. These properties are in addition to the stated requirements. There is no need to repeat the requirements here. These additional properties may not exist for every problem. Examples include conservation laws (like conservation of energy or mass) and known constraints on outputs, which are usually summarized in tabular form. A sample table is shown in Table 2

Table 2: Output Variables

Var	**Physical Constraints**
A_d	$A_d \geq 0$
R_d	$R_d \geq 0$

5 Requirements

This section provides the functional requirements, the business tasks that the software is expected to complete, and the nonfunctional requirements, the qualities that the software is expected to exhibit.

5.1 Functional Requirements

R1: Input the weather data and concrete degradation data.

R2: Utilize the input from the previous step to calculate the average corrosion rate and time to failure for the concrete.

R3: Generated prediction result.

5.2 Nonfunctional Requirements

NFR1: **Accuracy** With the given input, the system is capable of generating accurate results.

NFR2: **Reusable** The code is modularized.

6 Likely Changes

LC1: IM1 is the likely to changes.

7 Unlikely Changes

LC2: IM4 is fixed and unlikely to change.

8 Traceability Matrices and Graphs

The purpose of the traceability matrices is to provide easy references on what has to be additionally modified if a certain component is changed. Every time a component is changed, the items in the column of that component that are marked with an "X" may have to be modified as well. Table 3 shows the dependencies of theoretical models, general definitions, data definitions, and instance models with each other. Table **??** shows the dependencies of instance models, requirements, and data constraints on each other. Table **??** shows the dependencies of theoretical models, general definitions, data definitions, instance models, and likely changes on the assumptions.

	TM1	TM2	DD1	DD2	IM1	IM2	IM3
TM1							
TM2							
DD1		X					
DD2		X					
IM1							
IM2							
IM3							

Table 3: Traceability Matrix Showing the Connections Between Items of Different Sections

9 Values of Auxiliary Constants

Symbol	Description	Value	Unit
A_d	Accumulated deterioration at time t_y	24	mm
t_y	Time to failure	36	years
n	Time order	1	-
k_d	Factors influencing deterioration	4	mm/years
t_f	Time to failure	144	years

Table 4: Caption

References

[1] Nikitha Krithnan and W. Spencer Smith. *Software Requirements Specification for GlassBR.* https://jacquescarette.github.io/Drasil/examples/glassbr/SRS/srs/GlassBR_SRS.html

[2] *Historical Data.* (n.d.). Government of Canada. https://climate.weather.gc.ca/historical_data/search_historic_data_e.html

[3] Clifton, J. R., Pommersheim, J. M. (1992). *Methods for Predicting Remaining Life of Concrete in Structures.* https://nvlpubs.nist.gov/nistpubs/Legacy/IR/nistir4954.pdf