A

Dissertation Report on

Service Life Prediction of ZP School Buildings

Submitted

in partial fulfilment of the requirements for the degree of

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by

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CERTIFICATE

This is certify that,Ms.Dige Vaibhavi Ravindra (Roll No-1827005) has successfully completed the dissertation work and submitted dissertation report on "Service Life Prediction of ZP School Buildings" for the partial fulfilment of the requirement for the degree of Master of Technology in Civil-Construction Management from Department of Civil Engineering, as per rules and regulations of Rajarambapu Institute of Technology,Rajaramnagar.

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DECLARATION

I declare that this report reflects my thoughts about the subject in my own words. I have sufficiently cited and referenced the original sources, referred or considered in this work. I have not misrepresented or fabricated or falsified any idea/data/fact/source in this my submission. I understand that any violation of the above will be cause for disciplinary action by the Institute.

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Abstract

This report presents a specific case study for estimating the service life of ZP school buildings in the Shahuwadi region of Maharashtra, India. Prediction of building components is evaluated by calculation of 'Condition Indices' followed by the 'Factor method'. For planning maintenance of any building it is necessary to have good information about building components and durability of materials. The construction works have to be maintained during their whole service life. Service life's knowledge becomes very important input data to guide designers, manufacturers and real estate owners in contributing for sustainability of whole building process. The case in consideration was applied to the data collected for a project to assess the condition of 30 schools that belong to selected study area. According to ISO:15686-1(ISO,2000) we have assigned values of 0.9,1,1.2 to each factor, according to whether the factor has positive, null or negative effect on elements service life. The factors were assigned based on brickwork, structural components, surface coating, metal components.

Later on, Weibulls analysis was applied which is widely used in reliability and life data analysis due to its versatility. Its important aspect is, how the shape parameter, scale parameter, affect the distribution characteristics as shape of probability density function, the reliability and failure rate. From this analysis, it was found that most of the components were deteriorated with factor of 0.9 and there is an immediate need of replacement of that damaged component.

Keywords: Service life prediction, school,building maitainance, defects, survey..

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Chapter 1

INTRODUCTION

1.1 General

A building is not a piece of transportation that by its use you can say it wears down. A building is different and it is really a part of a landscape. It becomes part of the city, of the treasury of the spaces of the city.Thus lifetime perspectives in construction must consider 'true' historical dimensions including-how performative needs may change overtime, and how the act of building becomes rooted in civilization.

1.2 Introduction

The sustainability of building process requires the control and planning of material and economic resources necessary for its life cycle. Design choices should be oriented towards building's components and products characterized by an economically reasonable working life, i.e. which requires economically and materially sustainable maintenance activities, considering the predicted service life.
With this aim different researches and standards have been developed at national and international level on durability evaluation. At international level ISO TC 59 SC14 Service Life planning and CIB W80 RILEM Service life prediction methodologies are developing durability evaluation methods to support service life planning.
Within the construction industry, refurbishment and maintenance strategies must also optimize the social and economic benefits of existing structures. In the present economic situation in which the funds available for such actions are limited, there

is a growing need to plan and prioritize the necessary maintenance work. The planning of such work is based on predicting the time when the critical elements of the buildings reach degradation levels that exceed acceptable values. To be able to make such predictions, methods must be developed of estimating the service life of building materials and components.

Considerable work has been carried out in the area of service life prediction as requisite tools for helping assess long-term environmental effects, for maintenance management of infrastructure systems, such as roads, bridges, waterways, water distribution and waste-water removal systems, or indeed for maintenance of building envelope systems, envelope components and related materials. Increasingly, building material and component manufacturers are seeking systematic methods to assess the likely risk to premature deterioration of existing products given specific climatic effects, or the most vulnerable exposure conditions of new products in specified systems.

1.3 Outline of project

The dissertation report is divided into following chapters. These chapter describes the different work conducted for study.

Chapter 1: This chapter is an introduction on service life prediction.

Chapter 2: This chapter includes the review of all the previous literatures, the literature gap from each of the papers are also enlisted in the chapter. In this chapter motivation of study and objectives of project work is given.

Chapter 3: This chapter includes the methodology adopted.

Chapter 4: This chapter includes Survey and visual inspection caried out for project.

Chapter 5: This chapter includes details of percentage loss calculated for the school buildings.

Chapter 6: This chapter includes weibulls analysis used for Service Life prediction.

Chapter 7: This chapter includes factor method for elements of school building.

Chapter 8: This chapter includes Results of the project.

Chapter 9: This chapter includes Conclusion of the project.

1.4 Closure

In this section, we have introduced about building maintainance and service life.

Chapter 2

LITERATURE SURVEY

2.1 General

In this section, the present theories and practices related to the "Service life prediction of building components" were studied by referring the published journals, books and conferences. A literature review to analyze the recorded service life prediction history is used for this special type of analysis.

2.2 Literature review

2.2.1 Mark Alexander, Hans Beushausen (2019), "Durability, service life prediction, and modelling for reinforced concrete".

Ever increasing attention is being paid to deterioration prediction and service life modelling of reinforced concrete structures. Research has progressed to a stage where service life models and design philosophies are, to varying degrees, included in some codes and standards, such as the fib Model Codes and ISO 13823. This has helped to base practical durability design on sound engineering approaches. This paper reviews service life modelling and prediction, and service life design, covering limit state design philosophies and deterioration models. An overview on recent developments, and a critical review on common assumptions in service life modelling and on the application and limitations of the various approaches, are presented. It is emphasized that design approaches and models need to be validated with field observations. It is argued that a performance-based approach is the most suitable engineering tool for durability design. [1].

2.2.2 Karim El-Dash (May 2011), "Service Life Prediction for Buildings Exposed to Severe Weather".

This paper presents a specific case study for estimating the service life of public buildings in the harsh weather of Kuwait using the factor method. Estimating the service life helps enhance the sustainability of these buildings and controls some economic aspects. The case in consideration was applied to the data collected for a project to assess the structural behavior of twenty-six buildings that belong to Kuwait University. The buildings were assessed by visual inspection, material testing, and structural analysis. The findings of these investigations guided the working team to assign the values of the different factors used in the prediction process. The factors were predicted in a probabilistic approach to consider the inherent variability in the construction components and the surrounding effects. The results of the service life prediction provide a perspective for the expected life span of buildings in similar conditions [2].

2.2.3 Yasuhiro Mori P and Bruce R. Ellingwood (1993), Reliability-based service-life assessment of aging concrete structures".

Concrete structures may be affected by aging or changes in strength and stiffness beyond the baseline conditions assumed for design. These changes may impair the safety and serviceability of the structure, and should be considered as part of the process by which a structure is evaluated for continued future service. Methods are being developed using structural reliability principles to evaluate timedependent reliability of reinforced or prestressed concrete structures. These methods enable the impact on safety and serviceability of uncertainties in loading conditions,structural strength, and strength degradation due to aggressive environmental stressors to be assessed qualitatively. A probability-based method to evaluate time-dependent reliability of components and systems was presented, and the sensitivity of the reliability to various parameters describing load occurrence and strength degradation was illustrated using simple examples [3].

2.2.4 Sotiris Demisa, Vagelis G. Papadakis (2019), “Durability design process of reinforced concrete structures - Service life estimation, problems and perspectives”.

The need for a structured durability design process of reinforced concrete elements is strongly emphasized in the current study. Under such a framework, concrete service life estimation tools (SLTs) can be vital aids. Their utilization however is not an easy process and might lead to confusing results for the same element under the same harsh environment, as it is presented via a case study in this work. The reasons for such a behavior are explained and the next steps and research actions that have to be taken in establishing a widely accepted durability design process are discussed [4].

2.2.5 B. Martín-Pérez and Z. Lounis (JAN 2003), “Numerical modelling of service life of reinforced concrete structures”.

This paper presents an approach for service life prediction of reinforced concrete structures exposed to chloride environments that combines a finite element modeling of the chloride transport and a reliability-based analytical model for onset of damage and its accumulation. Service life is defined as the time until damage accumulation reaches an unacceptable level or ‘limit state’By using Monte Carlo simulation, the probabilistic distributions of the chloride penetration front and corrosion initiation time are generated. The proposed approach is illustrated on a reinforced concrete bridge deck exposed to chlorides from de-icing salts [5].

2.2.6 Johann Mc Duling , Emile Horak , Chris Cloete (2008), “Service Life Prediction Beyond the ‘Factor Method”.

The current ‘state of the art’ Factor Method [ISO 15686-1:2000] for service life prediction calculates an estimated service life, but not changes in condition.The application of the stochastic Markov Chain is restricted by limited availability of historic performance data on degradation of building materials required to populate transition probability matrices.This paper, based on a PhD thesis, looks at the application of neuro-fuzzy artificial intelligence to translate expert knowledge into probability values to supplement historic performance data for the development of Markovian transitional probability matrices, towards prediction of service life, condition changes over time, and effects of maintenance levels on service life of buildings [6].

2.2.7 G. HED (1999), "Service life planning of building components".

The study was connected to a demonstration construction scheme and was integrated in the design and construction of a building. The study was performed in accordance with the draft standard ISO/DIS 15686.1 Buildings: Service life planning, and one aim was to test, evaluate and give input to further development of the standard. This paper will discuss this approach and discuss how available service life data can be collected and evaluated. Examples of service-life predictions are also shown [7].

2.2.8 G Morcous and H Rivard (2006) "Service life prediction of low slope roof components in building".

This paper presents the development of probabilistic models for the service life prediction of low-slope roof components (i.e. membrane and flashing). Data use for model development are collected within the Building Envelope Life Cycle Asset Management (BELCAM) research project. The parameters that significantly affect the deterioration of built up roof (BUR) membrane and flashing are identified through statistical tests (i.e. correlation analysis and ANOVA). Transition probability matrices of Markov chain deterioration models are developed to be used in predicting the future condition of roof components [8].

2.2.9 Dhirendra Kumar, Sujeeeva Setunge and Indubhushan Patnaikuni(2010), "Prediction of life cycle expenditure for different categories of council buildings."

ISO presents a valuable methodology based on the factor method in the area of service life estimation but it requires considerable local knowledge about degradation of components and materials. The factor method on the other hand is fairly simple but identifies the main parameters influencing service life. The result, however, is only a single figure for service life and does not take into account the variability of the processes involved. A lot of work is being done in the area of service life prediction, but there is very little that can be readily used by building asset managers. Hence, there is a great need to develop a simple model which can be easily calibrated and used. The model proposed here can be easily implemented by practitioners and would be of benefit to infrastructure managers of city councils [9].

2.2.10 Life 365, Eucon, Duracon softwares for SLP.

A brief description of the software tools analyzed and studied in this study is presented in the current section.

- **LIFE 365** -Life-365 [17] is a widely used and established service life and lifecycle analysis (LCA) software package. It recognizes diffusion to be the dominant process in chloride ingress in concrete, disregarding the mechanism of chloride binding. The initiation time of corrosion is calculated based on 1-D (for slabs, beams) or 2-D (for columns) finite difference implementation of Fick's 2nd law of diffusion, by taking under consideration that the apparent diffusion coefficient is affected by time and temperature.

  According to the developers, Life-365 includes a probabilistic prediction of the initiation period of corrosion, although it has been argued to be more of a sensitivity analysis.

- **EUCON**-Eucon is a software tool, based on proven predictive models, according to performance-related methods for assessing durability, developed by the authors of this study [18,19], awarded by ACI, for the estimation of concrete service life under harsh environments. The physicochemical processes of Cl- diffusion in the aqueous phase, their adsorption and binding in the solid phase of concrete, and their desorption, are described by a non-linear partial differential equation.

  Solution of the latter allows the calculation of, the chlorides bound in the solid phase, the adequate concrete cover needed to sustain a corrosion free structure for a given service life and the estimation of the time required for the total chloride concentration surrounding the reinforcement, located at a distance c from surface, to increase over the threshold for depassivation.

- **DURACON** - Duracon [20] is a software package for probability-based durability analysis of concrete structure, developed under the scope of the DURACRETE [21] project. The software is based on a Monte Carlo Simulation of Fick's 2nd law of diffusion, adjusted to allow the time dependency of the chloride diffusivity and the effect of temperature. The model also incorporates the stochastic nature of the individual durability parameters.

The fib MC SLD developed under the framework of the International Federation for Structural Concrete (fib), presented in the Model Code (MC) for Service Life Design (SLD), offers a full probabilistic design approach for the modeling of chloride induced corrosion in uncracked concrete [22]. It has been developed within the research projects DuraCrete and DARTS (that's why is very similar to Duracon).

Main input parameters, in terms of Cl- exposure, of the software packages investigated.

Table 2.1: Input parameters of the software's Investigated

LIFE 365	EUCON	DURACON/fib MC SLD
1.Definition of structure and material properties Type of structure Thickness/cover/w/c, %FA,SF,Slag, protective systems	Cement type, Concrete constituents, w/c, additions, Air content, Materials oxide analysis, Component thickness	Concrete cover
2. Exposure condition Surface Cl- (kg/m3 conc.) Manual/profile/Automatic, Time to max Cl- surface (years), Critical Cl-, Temperature	Surface Cl- (kg/m3 sol) Manual, Automatic cation associated to Cl- (Na+/Ca2+) Initial Cl- (kg/m3 sol) Critical (total) Cl- (kg/m3 conc.)	Surface/critical Cl-(% wt conc.) Temperature
3.Chloride diffusion coefficient Apparent diff. coef. D28 (x 10–12 m2/s) Maturity factor m	Intrinsic diff. coef. (x 10–12 m2/s), FA/SF efficiency factor for Cl penetration, Equilibrium constant for Cl- binding	DApparent, t0 (x 10–12 m2/s) Factor for time dependence of diff. coeff.
4.Time related factor Propagation (years) Hydration (years)	Service life (SL)years	SL (years) t exposure (days) testing (days)
5.Probabilistic Aspects COV(%) of input	NO	SD/distribution

2.3 Research Gap

The research papers studied showed that the experimental study done previously was using 'Limit performance method', Life365, Eucon, Duracon, software, which were time consuming and costly. Whereas, here the study of service life prediction will be analyzed by calculation of 'Condition Indices' ,'Factor Method', followed by 'Weibull's degradation curve' which may be less time consuming and economical method.

2.4 Objectives

The objectives of this project work are -

• To perform condition assessment of ZP school buildings.

• To analyze the survey data and predict service life of ZP school buildings.

• To prepare a report and recommend the research results to Kolhapur Education Department

2.5 Closure

In this section, we have studied about literatures studied for the project.

Chapter 3

RESEARCH METHODLOGY

3.1 General

In this section we will study about research gap, problem statement, objective and methodology of project.

3.2 Problem Statement

The structural health of the old constructions goes on depleting after consecutive years. The environmental conditions adversely affects the old buildings and the human health. Thus it is important to know the service life of building for its repair and maintenance.

3.3 Proposed Methodology

The ZP schools under Shahuwadi Taluka were taken under consideration. These schools were evaluated based on their component deterioration . A checklist was prepared and the schools were assessed based on that checklist. The percentage losses of every individual component was calculated followed by condition indices. Further, the factor method was applied in which various factors according to the level of degradation had been assigned according to ISO-15686-1:2011 (Part 1,2 and 8). Weibuls analysis was applied to study the degradation curves .The service life of building components was predicted with the application of above mentioned methods.

Methodology adopted for research work is shown in Figure no. 3.1

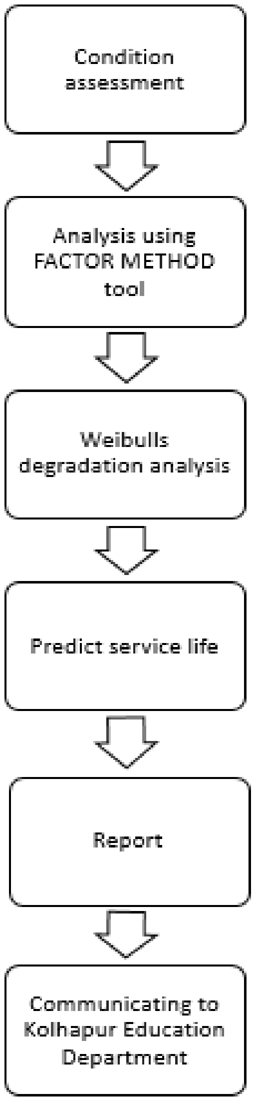


Figure 3.1: Methodology

3.4 Closure

In this section, we have studied about problem statement and methodology of project.

Chapter 4

SURVEY AND VISUAL INSPECTION

4.1 General

In this section, we will see about the data collection, survey of schools and defects observed. Also visual Inspection of school buildings.

4.2 Survey of ZP schools under consideration

Following table shows list of centers and schools in centers.

4.2.1 School information

Following table shows information of schools.it includes schoolname, year of construction, carpet area of school, number of classrooms, type of structure, number of students, building renovation information.

4.2.2 Defects observed in visual inspections

Following table shows Defects observed in visual inspections.

Table 4.1: Center information

No	Center name	School name
1	Bambavade	CHARAN
2	Bambavade	DONOLI
3	Bambavade	THERGAON
4	Bambavade	VHARKATWADI
5	Bambavade	BHADALE
6	Bambavade	HANMANTWADI
7	Bambavade	SUPATRE
8	Bambavade	CENTER SCHOOL BAMBAVADE
9	Bambavade	SAIDAPUR
10	Bambavade	KHUTALWADI
11	Bambavade	GOGAVE
12	Bambavade	GOGAVE HIGH
13	Bambavade	MAHATMA GANDHI BAMBAVADE
14	Bambavade	NEW ENGLISH SUPATRE
15	Bambavade	RAMGIRI CHARAN
16	Pishavi	POWARWADI
17	Pishavi	PISHAVI DHAN
18	Pishavi	JIVAN SALASHI
19	Pishavi	VHANAGADEWADI
20	Pishavi	VAREWADI
21	Pishavi	BHOSALEWADI
22	Pishavi	PISHVI
23	Pishavi	SONAVADE
24	Pishavi	KUMBHARWADI
25	Pishavi	KELEWADI
26	Pishavi	KHOTWADI
27	Pishavi	UDAY HIGH PISHAVI
28	Pishavi	SHIV SHAMBHU HIGH SALASHI
29	Pishavi	KUMBHARWADI HIGH

Table 4.2: School information

School name	**Year of constr.**	**Carpet area sq.ft**	**No. rooms**	**Type of structure**	**Is buiding renovated?**	**Yr. of renov.**
Charan	2012-13	7000	11	Load bearing	No	No
				stone masonary		
Khutalwadi	1958	5000	6	Load bearing	No	No
				stone masonary		
Supatre	1978	3000	4	Load bearing	requirement	2017
				stone masonary		
Kumbharwadi	1969	3000	1	Load bearing	No	No
				stone masonary		
Warewadi	2011-12	5500	7	Load bearing	requirement	2018
				stone masonary		
Maha. gandhi	1996	7000	12	Load bearing-	No	No
				stone masonary		
Thergaon	1970	6000	9	Load bearing-	No	No
				stone masonary		

School name	Year of constr.	Carpet area sq.ft	No. rooms	Type of structure	Is buiding renovated?	Yr. of renov.
Ramgiri charan	1980	3500	5	Load bearing-	No	No
				stone masonary		
Bhosalewadi	2007-08	2000	2	Load bearing-	No	No
	expansion2016			stone masonary		
Donoli	2007-08	5000	9	Load bearing	Yes	Aug-19
				stone masonary		
Vhanagdewadi	2008	3000	3	Load bearing	No	No
				stone masonary		
Kelewadi	2007	3000	2	Load bearing	No	No
				stone masonary		
Powarwadi	1984	4500	2	Load bearing	No	No
				brick masonary		
Salashi	2009	5000	11	Load bearing	No	No
				stone masonary		
Udyahigh, Pishavi	1976	3500	5	Load bearing	No	No
				stone masonary		
Sonavde	2011 - 12	5000	4	Load bearing	Yes	2019
				stone masonary		
Hanmantwadi	1985	2500	2	Load bearin	No	No
Centreschool,	1940	2 acre	11	Load bearing	Yes	2011
				stone masonary		
Khotwadi	1996	2500		Load bearing		No

Table 4.3: Defects observed in visual inspections

Defects observed in visual inspections						
Sr.no	**Defect**	**Type of Defect**				
1	**Cracks**	Longitidnal	Expansion	Transverse	Vertical	Diagonal
2	**Upliftingof**	Cracking	Buckling	Widening of the		
	flooring tiles			crack of the tile		
3	**Failure of**	Physical	Excessive	Dimensional	Chemical	
	wooden column	decay	moisture	instability	deterioration.	
4	**Leakage**	Roof	Floor	Ceiling	Wall	
5	**Rusting**	Stress	Localized	Surface	Crevice	
6	**Plaster**	Blistering	Cracks	Efflorescence	Flaking	Peeling
7	**Defect in**	Dislocation	Tilting	Cracking	Uneven	Depression
	paving blocks				surface	
8	**Defects in**	Wearing	Bending	Rusting	Cracking	
	roofsheet	out				

4.3 Visual inspection of structural defects of school buildings

4.3.1 Jivan Salashi School

Figure 4.1: Jivan Salashi School

DEFECTS OBSERVED:

Cracks occurring in timber columns often result from the differences between the drying speed in interior layers and outer ones. The drying stresses will build up if the outer layers are dried to a level that is much lower than the fibre saturation point while the interior is still saturated Rupture in timber occurs and, in consequence, cracks occur if the drying stress exceeds the strength perpendicular to the grain.

4.3.2 Charan School

Figure 4.2: Charan School

DEFECTS OBSERVED:

Cut edges on a steel roof will experience edge creep, which is minimal rusting occurring at the cut edge. Many details in a standing seam metal roof have folds or hemmed edges that conceal the cut edge of the metal Vertical and diagonal cracks in concrete walls typically indicate foundation movement. If a vertical crack widens at the top or bottom, the wall is either settling or gradually heaving, which may present serious issues. Spalling of the mortar and brick will occur due to the expansive nature of water. This happens when excessive moisture enters the walls.

4.3.3 Bhadale School

Figure 4.3: Bhadale School

DEFECTS OBSERVED:

The metal windows have been rusted to some extent and it is form of surface rusting. Without the required servicing and maintenance, hinges may become too tight to operate, rivets may loosen up and screws may be corroded that shorten their life-span. The purlins under the manglorian roof tiles have been eroded which may lead to service failure. The W.C are not in proper condition due to falling off of bricks from the walls. Also the roof has been subjected to dampness and can be a serious matter, particularly to buildings located near water sources. Dampness led to deterioration of building structures and also damage to the furnishings.

4.4 Closure

In this section, we have seen about the data collection, survey of schools and defects observed. Also visual Inspection of school buildings.

Chapter 5

PERCENTAGE LOSS CALCULATIONS

5.1 General

In this chapter we will study about the percentage loss calculation of various defects observed.

5.2 Percentage loss calculations of defects observed

Table 5.1: Percentage Loss Calculation

Sr. no	School name	Component Component	Defected Area	Total Area	Percentage loss
1	Bhosalewadi School	Cracks in wall 1	15*20sq.ft	5*8sq.ft	13.33
2	Bhosalewadi School	Cracks in wall 2	10*2sq.ft	6*5sq.ft	15
3	Bhosalewadi School	Dislocation of tiles	25*20 sq.ft	4*4*2 = 32sq.ft	6.4
4	Bhosalewadi School	Roof leakage	25*20sq.ft	265sq.ft	53
5	Charan school	Vegetation	4*40sq.ft	128sq.ft	80
6	Charan school	Wall cracks	20*15sq.ft	7*4sq.ft	9.33
7	Charan school	Concrete spalling	10*4 sq.ft 10*4 sq.ft	100	
8	Charan school	Column paint peel	5*1.5sq.ft	5*1.5sq.ft	100
9	Centre school	Roof moisture	15*20sq.ft	10*20sq.ft	66.66
10	Centre school	Leakage in walls	15*20sq.ft	15*20sq.ft	100
11	Centre school	Broken roof	13*15= 214.4 sq.ft	36.38 sq.ft	16.96
12	Centre school	Door frame- Spalling	17sq.ft	13.6sq.ft	80
13	Donoli School	vegetation on chajja	15*13sq.ft	6*13sq.ft	10.76
14	Donoli School	Staining	3.5*2sq.ft	6.65sq.ft	95

Following table shows percentage loss calculation.

Sr.	School	Component	Total	Defected	Percentage
no	name	Component	Area	Area	loss
15	Donoli School	Breaking of tiles	374sq.ft	3*7sq.ft	5.61
16	Donoli School	peeling of paint	411.4sq.ft	411.4sq.ft	100
17	Donoli School	cracking	15*4 sq.ft	15*3 sq.ft	75
18	Hanmantawadi School	spalling of ramp	4*20sq.ft	2*2sq.ft	5
19	Hanmantawadi School	varandah breakage	8*25sq.ft	15*2sq.ft	15
20	Hanmantawadi School	efflorescence	3*15sq.ft	38.25sq.ft	85
21	Hanmantawadi School	cracking	15*10 sq.ft	2*5 sq.ft	6.67
22	Jivan salshi school	rusting of windows	4*4sq.ft	2*4sq.ft	50
23	Jivan salshi school	Leak & stains	15*20sq.ft	15*20sq.ft	100
24	Jivan salshi school	Shear cracks	4*3sq.ft	3*1sq.ft	25
25	Jivan salshi school	Blisters	5*7sq.ft	5*7 sq.ft	100
26	Kelewadi school	staircase Deterioration	4.5*4sq.ft	4*4sq.ft	88.88
27	Kelewadi school	Rotten wooden	8*15sq.ft	1*15sq.ft	12.5
28	Kelewadi school	vegetation	15*10sq.ft	4*8sq.ft	21.33
29	Kelewadi school	wall damage	15*10sq.ft	15*1sq.ft	10
30	Khutalwadi school	Cracks	4*20sq.ft	3*4sq.ft	15
31	Khutalwadi school	Rusting of window	3*4sq.ft	3*4sq.ft	100
32	Khutalwadi school	Loss of mortar	15*20sq.ft	4.5*3sq.ft	4.5
33	Khutalwadi school	Deterioration of sloping wall	80sq.ft	40sq.ft	50
34	Kumbharwadi school	Loss of mortar	15*20sq.ft	6*1sq.ft	3
35	Kumbharwadi school	Roof tile Breakage	15*20sq.ft	2*2sq.ft	1.33
36	Kumbharwadi school	Corner cracks	6*12sq.ft	1*8sq.ft	11.11
37	Kumbharwadi school	Damage of wooden	0.5*0.5*7sq.ft	0.5*0.5*7sq.ft	100
38	Mahatma Gandhi	window Breakage	4*4sq.ft	4*4sq.ft	100
39	Mahatma Gandhi	Sloping in Wrong direction	3*2sq.ft	3*2sq.ft	100
40	Mahatma Gandhi	Spalling of concrete	5*20sq.ft	1*3sq.ft	3
41	Mahatma Gandhi	cracks	15*20sq.ft	5*2sq.ft	3.33
42	Khotwadi School	Damaged wooden	5*0.5sq.ft	5*0.5sq.ft	100
43	Khotwadi School	Andhari	5*0.75sq.ft	4*0.75sq.ft	90
44	Ramgiri Charan School	Blister and discolouration	15*20sq.ft	15*20sq.ft	100
45	Ramgiri Charan School	wearing out of windows	3*1sq.ft	2*1sq.ft	66.67
46	Ramgiri Charan School	Breaking of tiles	15*10sq.ft	9*1sq.ft	6
47	Powarwadi School	Cracks	15*20sq.ft	1*10sq.ft	3.33
48	Powarwadi School	Moss growth	13*25sq.ft	5*6sq.ft	9.23
49	Powarwadi School	cracks	15*20sq.ft	1*6sq.ft	2
50	Powarwadi School	Tile braking	25*20sq.ft	3*6sq.ft	3.6
50	Sonawade School	Broken wall	15*10sq.ft	4sq.ft	2.67
51	Sonawade School	Spalling	15*5sq.ft	6*4sq.ft	32
52	Sonawade School	Surface deterioration	5*2sq.ft	2.5*2sq.ft	50
53	Sonawade School	Displaced roof	2*15*10sq.ft	2*2sq.ft	1.33
54	Supatre School	Wooden Crack	15*1.5sq.ft	12*1.5sq.ft	80
55	Supatre School	peeled of paint	15*1.5sq.ft	15*1.5sq.ft	100

Table 5.2

Sr no	School name	Component	Total area	Defected area	Percentage loss
56	Supatre School	Black Board crack	6*4sq.ft	1*4sq.ft	16.67
57	Supatre School	Damaged Wall	15*20sq.ft	11*3sq.ft	11
58	Thergaon	Deteriorated support frames	55*1	55*1	100%
59	Thergaon	Patching of supports	15*0.5	5*0.5	33.33%
60	Thergaon	Blister and peeling off	15*20	15*20	100%
61	Thergaon	Rotten wooden columns	0.5*8*0.5	0.5*8*0.5	100%
62	Udya high pishavi	Breaking of manglorian tiles	15*10	7	4.67%
63	Udya high pishavi	Staining of window	2*4	2*4	100%
64	Udya high pishavi	Peeling off- exterior paint	15*13	6*4	12.3%
65	Vhanagdewadi	Fungi attacked wall	10*12	10*10	83.33%
66	Vhanagdewadi	Broken surface floor	5*8	5*5	62.5%
67	Warewadi	Shear cracks	15*20	6*4	8
68	Warewadi	Leak and moisture on wall	15*20	5*20	33.34%
69	Warewadi	Moss and fungus –external wall	15*10	15*10	100%
70	Warewadi	Spalling of concrete	10*12	2*2	3.33%
71	Bhadle	Corroded bar	12*3	3*2	16.67%
72	Bhadle	Concrete layout	5.5*8	5*0.75	9.37%
73	Bhadle	Horizontal cracks in wall	15*20	20*2	13.4%
74	Bhadle	Roof leakage	374	280	75%

Figure 5.1: Bricks Displacement

Figure 5.2: Breaking of manglorian tiles

5.3 Closure

In this chapter we have studied about the percentage loss calculation of various defects observed.

Chapter 6

WEIBULL'S ANALYSIS

6.1 General

In this chapter we will study about weibulls analysis.

6.2 Condition Index Assessment -

Condition is assessed through visual inspection and hence the repair priorities may differ from person to person based on the individuals' perception as mentioned earlier, therefore would not be unique. A questionnaire survey is formulated to resolve this issue, for manifestations of various corrosion distresses in RC buildings namely 1. Rusting rust stains and cracks; 2. Delamination/spalling/loss in steel section; 3. Poor workmanship ,honeycombing and moisture marks. The repair priorities are classified as "low," "medium," "high," etc., Condition ratings define the various condition states.

Main objective of condition assessment are to place the building into one of the following three categories:

A :The building has not shown any signs of distress and It satisfies all the safety and serviceability requirements according to relevant Codes of practice, hence no action is needed towards retrofitting.

B :The building is seen to be deficient (or distressed) but it can be repaired and strengthened to satisfy the Codal safety requirements or performance criteria set by the user.

C :The building is badly damaged. It is to be demolished and a new building may be built, build back better.

6.3 Limitation

The common limitation with visual inspection is that, it only allows qualitative assessment and therefore, only states whether a particular distress condition is good, bad, very bad, etc. This limitation is unavoidable due to subjectivity, in interpretation of distress manifestation as well as in the corresponding repair priority and hence leads to inferences which are not defined precisely. Furthermore, these results cannot be generalized as the interpretation of visual manifestations of distresses may differ from person to person depending on their perception, eyesight, expertise and field knowledge.

6.4 Introduction

The 'Weibull distribution' named for its inventor, Waloddi Weibull, this distribution is widely used in reliability engineering and elsewhere due to its versatility and relative simplicity. A distribution is mathematically defined by its pdf equation. The most general expression of the Weibull pdf is given by the three-parameter Weibull distribution expression, or:

$$f(T) = \frac{\beta}{\eta}\left(\frac{T-\gamma}{\eta}\right)^{\beta-1} e^{-\left(\frac{T-\gamma}{\eta}\right)^{\beta}}$$

$$f(T) \geq 0,\ T \geq 0 \text{ or } \gamma,\ \beta > 0,\ \eta > 0,\ -\infty < \gamma < \infty$$

6.5 Characteristics of 'Weibulls Distribution'

In Weibulls distribution,

- Beta is the shape parameter, also known as the Weibull slope
- Eta is the scale parameter
- Delta is the location parameter

Frequently, the location parameter is not used, and the value for this parameter can be set to zero. When this is the case, the pdf equation reduces to that of the two-parameter Weibull distribution. There is also a form of the Weibull distribution known as the one-parameter Weibull distribution. This in fact takes the same form as the two-parameter Weibull pdf, the only difference being that the value of shape parameter is assumed to be known beforehand. This assumption means that only the scale parameter needs be estimated, allowing for analysis of small data sets. It is recommended that the analyst have a very good and justifiable estimate for shape parameter before using the one-parameter Weibull distribution for analysis.

As was mentioned previously, the Weibull distribution is widely used in reliability and life data analysis due to its versatility. Depending on the values of the parameters, the Weibull distribution can be used to model a variety of life behaviors. An important aspect of the Weibull distribution is how the values of the shape parameter, and the scale parameter, affect such distribution characteristics as the shape of the pdf curve, the reliability and the failure rate.

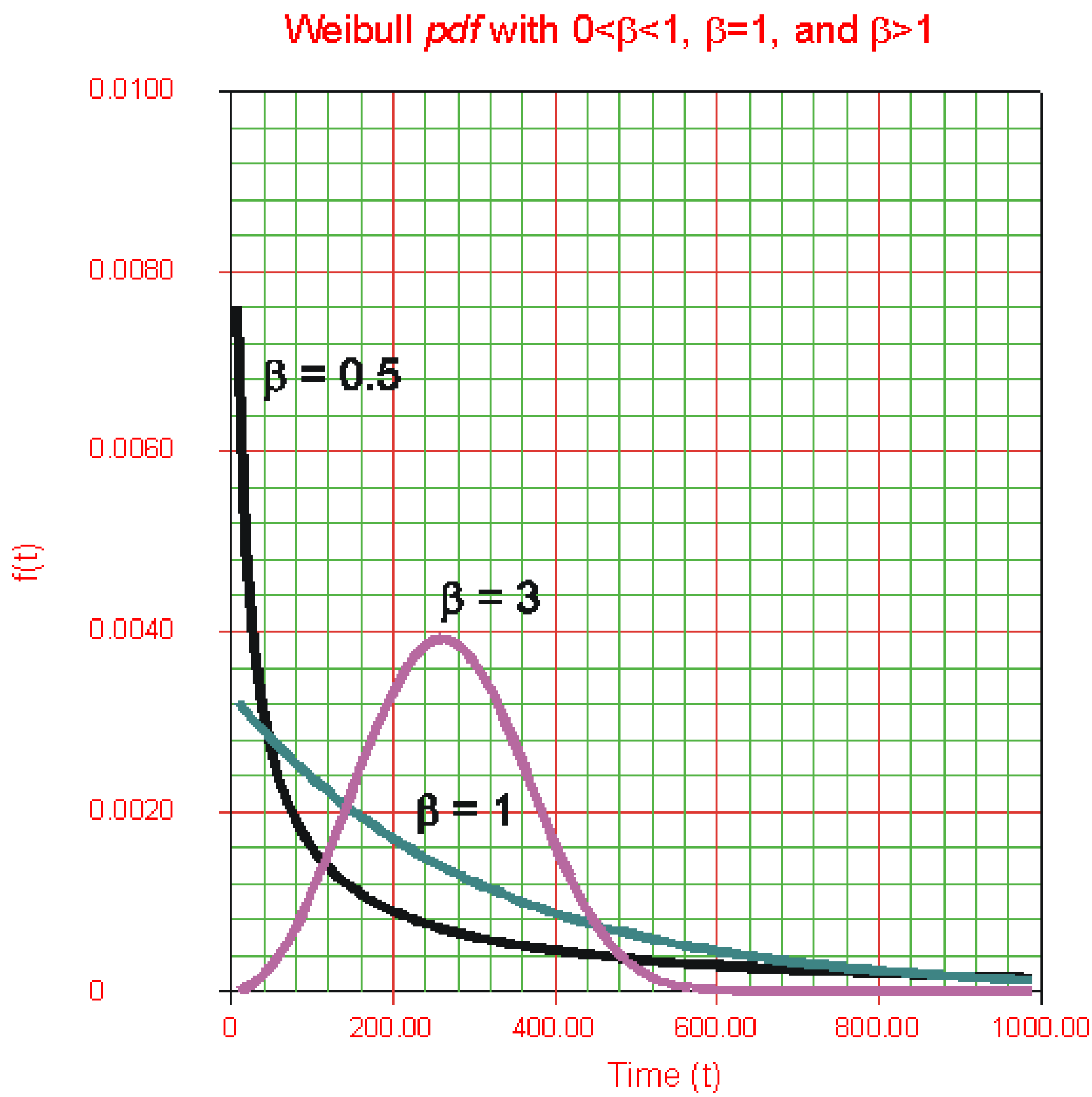


Figure 6.1: Weibulls graph 1

6.6 Weibulls scale parameter :

A change in the scale parameter, has the same effect on the distribution as a change of the abscissa scale. Increasing the value of scale parameter while holding shape parameter constant has the effect of stretching out the pdf. Since the area under a pdf curve is a constant value of one, the "peak" of the pdf curve will also decrease with the increase of n, as indicated in the following figure.

• If n is increased, while beta and delta are kept the same, the distribution gets stretched out to the right and its height decreases, while maintaining its shape and location.

• If n is decreased, while beta and eta are kept the same, the distribution gets pushed in towards the left (i.e., towards its beginning or towards 0 or eta), and its height increases.

• n has the same unit as T, such as hours, miles, cycles, actuations, etc.

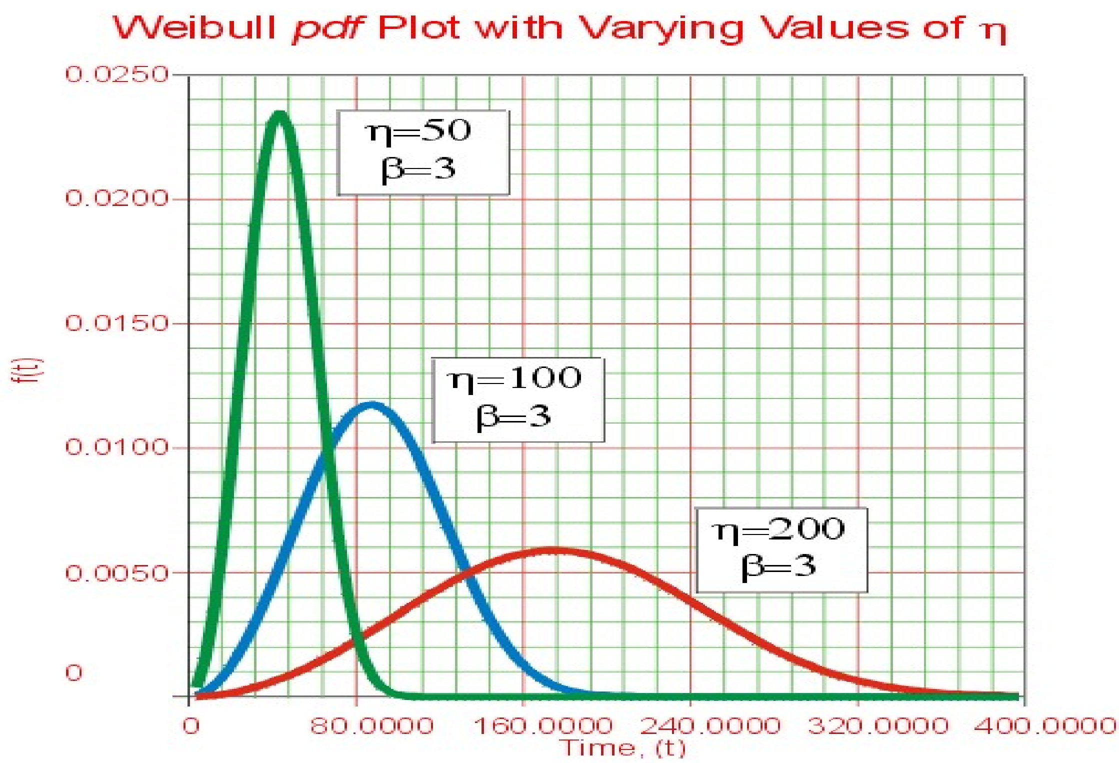


Figure 6.2: Weibulls graph 2

6.7 Estimation of weibulls parameters

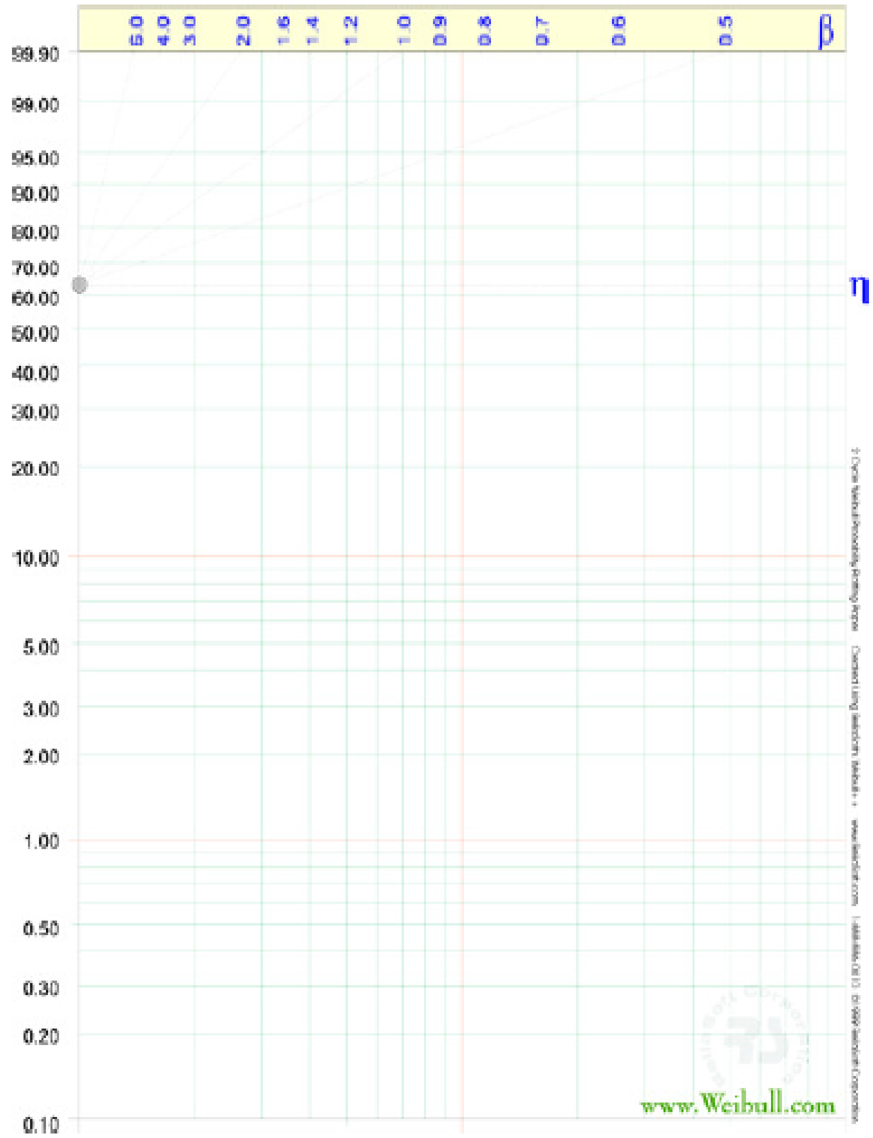


Figure 6.3: Weibulls parameter calculator

• Using the weibull probability graph, weibull parameters have been calculated for various service life periods of building components.

• Based on the above parameters and using equation (2 parameter weibull analysis) the degradation curves are drawn using Microsoft Excel.

'x' axis represents time and 'y' represents the condition index of building component ranging from 100 at the time of installation and near to 0 at the end of service life.

By considering various recommended service lives of buildings the deterioration/degradation curves have been plotted.

• Condition and Reliability are related as follows:

a) Condition and reliability are maximum (100) at or near the start of the service life,

b) Condition and reliability approach the minimum state (0) asymptotically,

c) Condition and reliability deteriorate unless corrective action is performed, and

d) As condition deteriorates, reliability likewise decreases

6.8 Weibull parameters estimation:

School under consideration – CHARAN

Defect- Peeling off of column paint =5 years

Table 6.1: Age of School

t (years)	n	B	CI'	Age of school= 8 years	
0.25	3.5	3	0.999636	t(years)	CI'
0.5	3.5	3	0.997089	0.5	0.997089
0.75	3.5	3	0.990209	1	0.976946
1	3.5	3	0.976946	1.5	0.924301
1.25	3.5	3	0.955468	2	0.829785
1.5	3.5	3	0.924301	2.5	0.694591
1.75	3.5	3	0.882497	3	0.532732
2	3.5	3	0.829785	3.5	0.367879
2.25	3.5	3	0.766692	4	0.224762
2.5	3.5	3	0.694591	4.5	0.119389
2.75	3.5	3	0.615661	5	0.05418
3	3.5	3	0.532732		
3.25	3.5	3	0.449034		
3.5	3.5	3	0.367879		
3.75	3.5	3	0.292305		
4	3.5	3	0.224762		
4.25	3.5	3	0.166885		
4.5	3.5	3	0.119389		
4.75	3.5	3	0.082115		
5	3.5	3	0.05418		

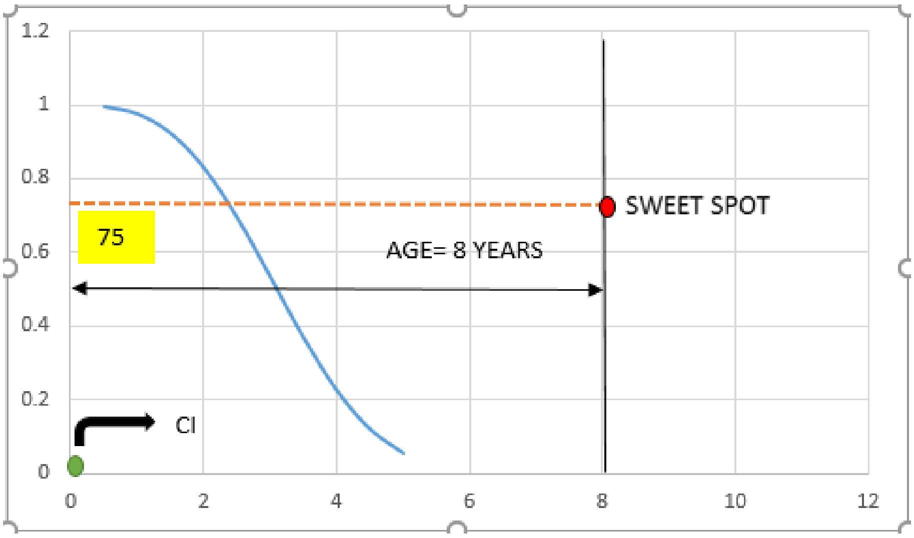


Figure 6.4: Weibull degradation curve (Charan school)

6.9 Degradation curves –

The degradation curves plotted with condition index on 'Y' axis and time on 'X' axis show degradation pattern for building components, research has shown that optimized maintenance and repairs performed at proper degradation level Condition Index (CI) will reduce the cost and improve the life of building components. CI in the range of 70–80 has been termed as sweet spot by many; where maintenance if done achieves optimization. It has also been clear that when CI drops below 40 the component loses its serviceability and needs to be replaced or rehabilitated, this calls for high amount invested may be due to negligence or illiteracy.

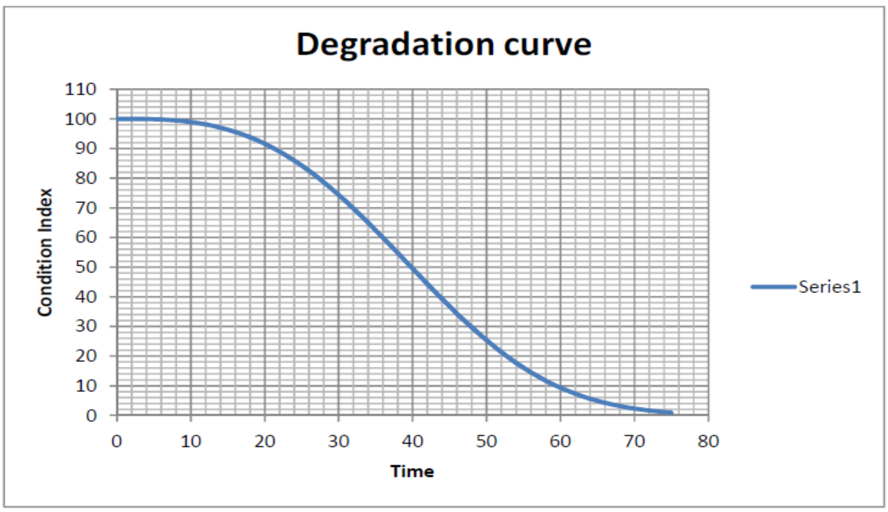
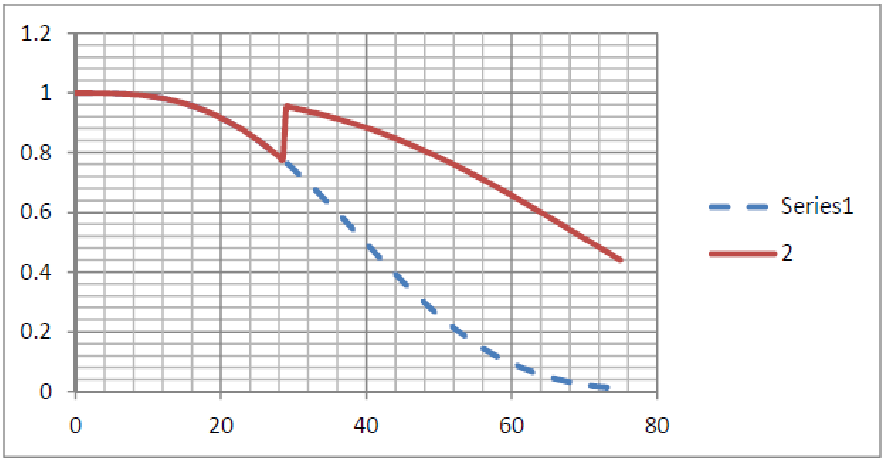


Figure 6.5: Degradation curve



Degradation Curve modification for repairs

Figure 6.6: Degradation curve

6.10 School name - Bhosalewadi

Component name - Wall plaster crack Following table shows percentage loss calculations.

Table 6.2: percentage loss table

Direction	Defected area	Total area	Percent loss
N	15*20	15*20	100
S	10*20	10*20	100
E	15*20	15*20	100
W	0	0	0
			TOTAL=100%

Condition Index – 0

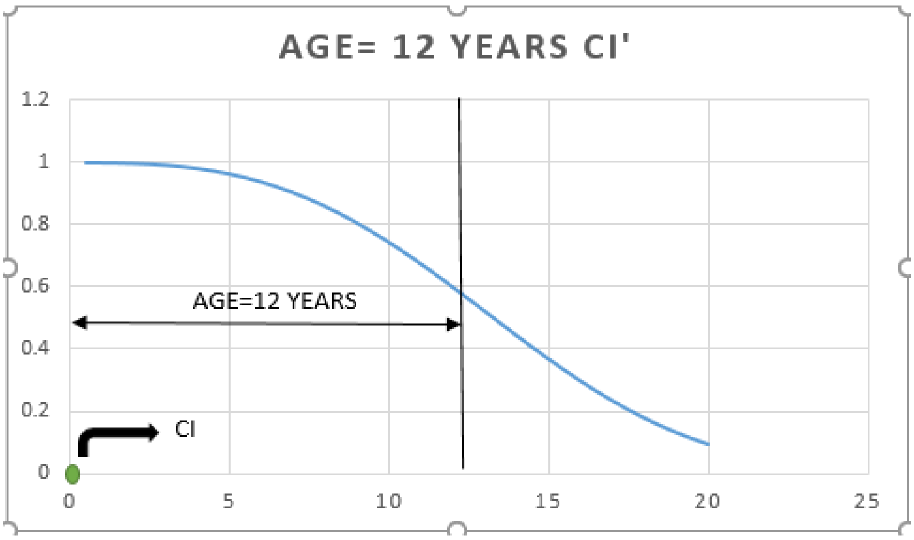


Figure 6.7: Degradation curve

CI=0

Indicates a factor of 0.9 , the component needs to be replaced.

6.11 School name – Centre school Bambawde.

Component name – Leakage in roof

Table 6.3: Percentage loss table

Direction	Defected area	Total area	Percent loss
N	15*20 sq.ft	15*20 sq.ft	100%
S	-		
E	-		
W	-		
			TOTAL= 100%

Condition Index - 0

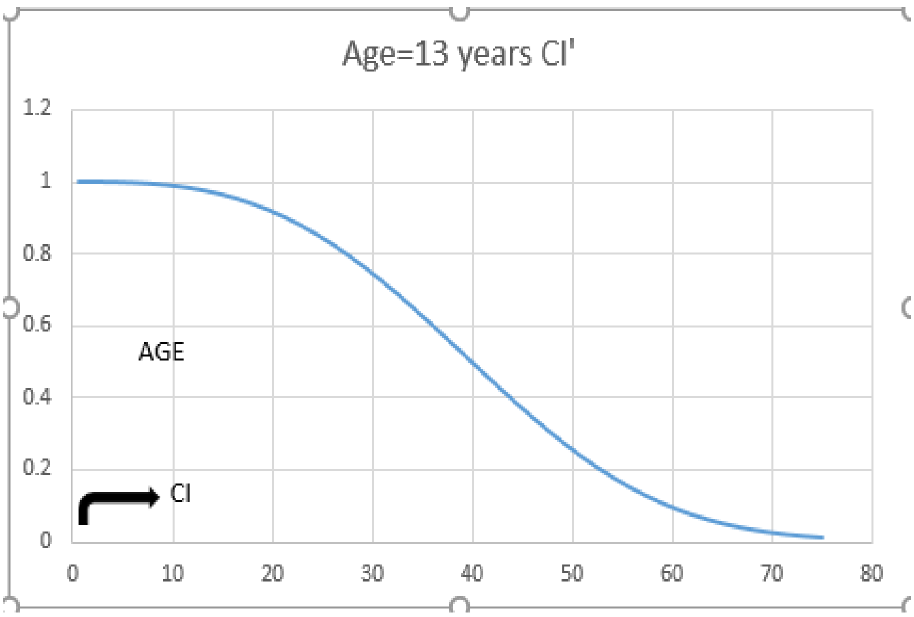


Figure 6.8: Degradation curve

CI=0

This indicates a factor of 0.9, component needs to be replaced.

6.12 School name - Charan.

Component name – Peeling off of column paint

Condition Index - 0

Table 6.4: Percentage loss

Direction	Defected area	Total area	Percent loss
N	5*1.5 sq.ft	5*1.5 sq.ft	100%
S	-		
E	-		
W	-		
			TOTAL=100%

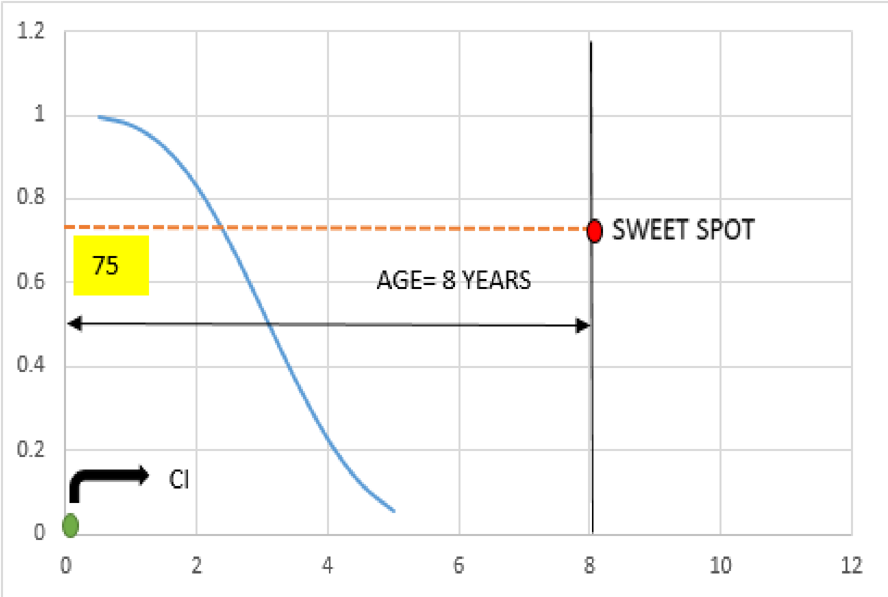


Figure 6.9: Degradation curve

CI=0

This indicates a factor of 0.9, component needs to be replaced.

6.13 School name - Donoli.

Component name – Breaking of Shahbadi tiles

Table 6.5: Percentage loss calculation

Direction	Defected area	Total area	Percent loss
N	3*7sq.ft	374sq.ft	5.61%
S	-		
E	-		
W	-		
			TOTAL= 5.61%

Condition Index - 94.39

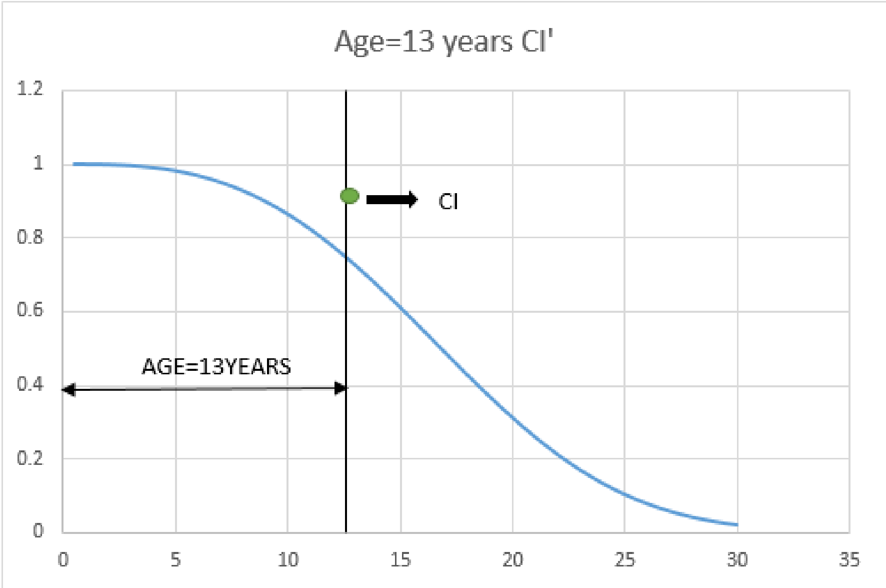


Figure 6.10: Degradation curve

CI=94.39

This indicates a factor of 1.2, component needs to be replaced.

6.14 Closure

In this chapter we have studied about weibulls analysis.

Chapter 7

FACTOR METHOD

7.1 General

In this section, we will study about information of factor method and calculation of service life by factor method.

7.2 Factor method

The factors method uses a deterministic approach that allows the service life of an element or system to be quantified under specific conditions, based on a reference service life that is modified by factors dependent on the specific conditions.
The method was initially promoted in Japan in the nineties (AIJ, 1993). ISO 15686 Service life planning describes this method initially in its Part 1, and more recently in Part 8. ISO 15686 Part 1 (ISO, 2000) describes the factors method and gives guidelines on how to calculate the reference service life and each of the factors involved.
The following factors are included: Factor A: Quality of the components; Factor B: Design level; Factor C: Work execution level; Factor E: External exposure conditions; Factor F: In-use conditions; Factor G: Maintenance level. The factors method can be expressed as a formula:
ESLC = RSLC x factor A x factor B x factor C x factor E x factor F x factor G. [1]. (ISO, 2000)
Where: ESLC; is estimated service life and RSLC is reference service life. To date, practical applications of the factors method have been rather limited and most of the cases published are described in [63 2015, 14(1) 60-68 [Ortega, L. – Serano,

B. – Fran, J.] Revista de la Construccion Journal of Construction theoretical studies that give examples of its use. This is due to the fact that those involved in the field (architects, builders, property owners and administrators) are not usually familiar with the method and also because of the need for useful values for the factors.

7.3 Interlinkage of 'CI' and 'Factor method'

Following table shows Interlinkage of 'CI' and 'Factor method'.

Table 7.1: Interlinkage of 'CI' and 'Factor method'

ZONE	CONDITION INDEX INDEX	CONDITION DESCRIPTION	RECOMMENDED ACTION	FACTORS
1	85-100	Excellent: No noticeable defects. Some aging or wear may be visible	Immediate action is not required	1.1
2	70-84	Very Good: Only minor deterioration or defects are evident	Immediate action is not required	1.1
3	55-69	Good: Some deterioration or defects are evident, but function is not significantly affected	Economic analysis of repair alternatives is recommended to determine appropriate action	1
4	40-54	Fair: Moderate deterioration. Function is still adequate	Economic analysis of repair alternatives is recommended to determine appropriate action	1
5	25-39	Poor: Serious deterioration in at least some portions of the structure. Function is inadequate.	Detailed evaluation is required to determine the need for repair, Rehabilitation or Reconstruction. Safety evaluation is Recommended.	0.9

Table 7.2: Interlinkage of 'CI' and 'Factor method'

ZONE	CONDITION INDEX INDEX	CONDITION DESCRIPTION	RECOMMENDED ACTION	FACTORS
6	10-24	Very Poor: Extensive deterioration. Barely Functional.	Detailed evaluation is required to determine the need for repair, Rehabilitation or Reconstruction. Safety evaluation is Recommended.	0.9
7	less than 9	Failed: No longer functions, General failure or complete failure of major structural component.	Detailed evaluation is required to determine the need for repair, Rehabilitation or Reconstruction. Safety evaluation is Recommended.	0.9

NOTE- ISO15686-1 (ISO, 2000) assigns values of 0.8, 1 and 1.2 to each factor, according to whether the factor has a positive, null or negative effect on the element's service life.

7.4 Application of proposed method :

The aim of the method is to estimate the service life of a construction system based on reference service life and correcting it according to certain factors dependent on the conditions of the system. ISO 15686 Part 1 (ISO, 2000) describes the factors method according to the formula given in [1].
Users of the method must fill in a table with the characteristics of the construction element under study, assigning specific factors to arrive at an estimate of service life, which should be greater than the design service life assigned to the element in the standards. If this is not so, steps should be taken to alter the design of the constructive system in order to lengthen its estimated service life.

7.5 Reference service life :

The reference service life (RSLC) is a term used in the factor method described in the ISO standard on Service life planning, ISO 15686-1. The factor method has been described in great detail in a number of publications [Hovde 2003] and in its essential form it provides for estimating the Service life of building products

,components or building systems. The factor method as pointed out by both Moser [2003] and Marteinsson [2003],is not a degradation model , but a a method by which to transfer knowledge on service life from reference conditions to project specific conditions and this is a method that is typically used in engineering design. The reference service life is a service life that a building or parts of a building (component) would expect (or is predicted to have) in a certain set of in use conditions (referred to as "reference set "of in-use conditions).The reference service life (RSLC) is used to estimate the service life of a building or its components (ESLC) on the basis of adjusting the reference service life through the use of various in-use conditions,or factors that relate to differences from the reference set in the quality off the materials, workmanship, environment and other factors that are known to alter these conditions .Or simply stated :

ESLC= RSLC *A*B*C*E*F*G.

The development of factor method and its applicability to different cases has been reported by Hovde [2003] and more elaborate methods have also recently been promoted by Moser [2003] .One key item in using the method as reviewed by Marteinsson [2003] is that of determining what the reference service life (RSL) of a product or component (RSLC) is prior to using the factor method.

With this in mind, considerable work has been prepared for identifying what reference service life of a product or component (RSLC) might be as described in the working draft of ISO-15686-8 [ISO 2001 b] .

In this working draft standard, guidance is provided in regards to the provision, selection, and formatting of RSLC data. Provision of data implies locating and assessing the usefulness of data that might exist with an organization. Once assessed, data may be used for the Factor method described in the standards. However, the focus has been made on providing a basic structure for reporting RSLC data so that some commonality among the different data sets could be achieved .It is also noted in ISO WD 15686-8 [ISO 2001 b] that few systematic studies on service life prediction exists and that there is an urgent need to gather relevant data to help demonstrate the concept.

7.6 Factors included in the method :

ISO 15686 Parte 1 (ISO 2000) describes the factors method and gives general indications on how to establish each factor. The present method proposes the use of factors given in the Factors Method section. The method proposed in this paper uses a greater number of factors than those included in the standards and assigns to each factor another set of factors that defines the concept proposed by ISO 15686-1 (ISO, 2000) for each construction element. The number of factors that define each concept varies according to the section and the construction element under study. Specific factors were selected, as has been indicated above, from an analysis of the factors that have an impact on the occurrence of the most common building defects.

7.7 Values assigned to each factor :

In the proposed method, each factor gives the user different selection options. According to the option selected, the factor will have a value lower, equal or higher than one. The estimated system service life is the result of multiplying reference service life by the value assigned to each of the factors. Figure3 shows an example. In its examples, ISO15686-1 (ISO, 2000) assigns values of 0.8, 1 and 1.2 to each factor, according to whether the factor has a positive, null or negative effect on the element's service life.

7.7.1 Brickwork

Following tables shows various factors in factor method.

Table 7.3: Factor E-for brickwork

FACTORS		ASSIGNED VALUE
E1:	Industrial pollution	0.9
Environmental class:	Inland urban environment	1
atmospheric	pollution	1.1
E2:	Rainfall zone of average I or II	0.9
Rain water exposure	Rainfall zone of average III or IV	1
frequency	Rainfall zone of average V	1.1
E3:	Wind exposure level V1	0.9
Wind exposure	Wind exposure level V2	1
level	Wind exposure level V3	1.1
Factor E – External exposure conditions		

Table 7.4: factor A for brickwork

FACTORS			ASSIGNED VALUE
A1:	Not used low suction bricks, or water repellent or vitrified.		0.967
waterproofness of	Used low suction bricks		1
brick masonary	Used water repellent or vitrified		1.1
A2:	Clay bricks with little efflorescence		0.967
clay bricks efflorescence	Clay bricks with no efflorescence		1
A3:	Yes	0.967	
Use of industrial mortars	No	1	
A4:Sort of masonary mortar	Mortar class M1 or M2.5	0.967	
	Mortar class M5	1	
	Mortar class 7 or more	1.1	
A5:Corrosion resistance of metal elements	Unprotected metal elements	0.967	
	Protected metal elements	1	
	Stainless steel	1.1	
Factor A –Components quality			

Table 7.5: factor B for brickwork

FACTORS		ASSIGNED VALUE
B1: Water leakage level	Water leakage level I or II according to CTE-DB-HS1(provided it keeps minimum water leakage level as per standard)	0.9
	Water leakage level III or IV according to CTE-DB-HS1(provided it keeps minimum water leakage level as per standard)	1
	Water leakage level V according to CTE-DB-HS1	1.1
B2:Distance between movement vertical joints	Distance between movement vertical joints more than 15m	0.9
	Distance between movement vertical joints between 12 and 15m	1
	Distance between movement vertical joint less than 12m	1.1
B3:Conditions of outer clay brick layer	Outer clay brick layer is supported by horizontal structure.	1
	Outer clay brick layer extends continuously front of the structure.	1.1
B4:Colour clay brick masonary	Dark	0.9
	Medium	1
	Clear	1.1
Factor B –Design level		

Table 7.6: Factor C for brickwork

FACTORS			ASSIGNED VALUE
	YES 1.1	NEUTRAL 1	NO 0.9
C1:Low complexity or risk			
C2:Good quality assurance and inspection routines			
C3:Defined working plan and experienced working designers			
Factor C- WORK EXECUTION LEVEL			

Table 7.7: Factor G for brickwork

FACTORS		ASSIGNED VALUE
G1: Accessibility to human facilities	There is no easy access for inspection and repair of those humid facilities, that if they have leak could cause damage to component.	0.9
	There is a partial accessibility for inspection and repair of those humid facilities, that if they have a leak could cause damage to component.	1
	There is total accessibility for inspection and repair of those humid facilities, that if they have a leak could cause damage to component.	1.1
G2:Incorporations of mechanism for cleaning	There is no provision in project of mechanism for cleaning	0.9
	There is provision in project of mechanism for cleaning	1
G3:Level of detail of maintenance plan	No maintenance plan	0.967
	Maintenance plan provides generic operations	1.0
	Maintenance plan provides specific operations for building construction, systems, elements and materials.	1.1
Factor G – Maintenance level		

Table 7.8: Factor F for brickwork

FACTORS		ASSIGNED VALUE
F1- Exposure to vandalism in heavy pedestrian traffic area and/or possibility of being vandalized	Commercial building located 0.967	
located in heavy pedestrian traffic area without possibility of being vandalized	No commercial building 1.00	
Factor F- Conditions of use		

7.7.2 Structural components [Beams/Columns/Slab]

Following tables shows the factors calculated for structural component.

Table 7.9: Factor A for structural component

FACTORS			ASSIGNED VALUE
A1:Honeycombing in element	Not used low suction bricks, or water repellent or vitrified.		0.967
	Used low suction bricks		1
	Used water repellent or vitrified		1.1
A2:Resistance to overloading	Low resistance		0.967
	High resistance		1
A3:Use of industrial concrete	Yes		0.967
	No	1	
A4:Sort of concrete	Mortar class M15 or M20		0.967
	Mortar class M20to M30	1	
	M30 or more		1.1
A5:Corrosion resistance of R/F steel	Steel exposed to surface and corroded		0.967
	Steel exposed and not corroded	1	
	No exposure to surface		1.1
Factor A –Components quality			

Table 7.10: Factor B for structural components

FACTORS		ASSIGNED VALUE
B1: Type of structure	Load bearing	0.967
	RCC	1
B2:Honeycombing effect	High amount of honeycombing	0.967
	Low amount of honeycombing	1
B3:Colour clay brick masonary	Dark	0.967
	Medium	1
	Clear	1.1
Factor B –Design level		

Table 7.11: Factor C for structural components

FACTORS			ASSIGNED VALUE
	YES 1.1	NEUTRAL 1	NO 0.9
C1:Low complexity or risk			
C2:Good quality assurance and inspection routines			
C3:Defined working plan and experienced working designers			
Factor C- WORK EXECUTION LEVEL			

Table 7.12: Factor G for strucutral components

FACTORS		ASSIGNED VALUE
G1: Accessibility to human facilities	There is no easy access for inspection and repair of those humid facilities, that if they have a leak could cause damage to component.	0.9
	There is a partial accessibility for inspection and repair of those humid facilities, that if they have a leak could cause damage to component.	1
	There is total accessibility for inspection and repair of those humid facilities, that if they have a leak could cause damage to component.	1.1
Factor G – Maintenance level		

Table 7.13: Factor F for structural components

FACTORS		ASSIGNED VALUE
F1- Exposure to vandalism	Commercial building located in heavy pedestrian traffic area and/ or possibility of being vandalized	0.967
	No commercial building located in heavy pedestrian traffic area without possibility of being vandalized	1.00
Factor F- Conditions of use		

7.7.3 Surface coating [Roof/tiles/paint]

Following tables shows factors for surface coatings.

Table 7.14: factor A for surface coatings

FACTORS		ASSIGNED VALUE		
		Roof	Tiles	Paint
A1:Waterproofness	Used	1	-	-
	Not used	0.967	-	-
A2:Use of standard materials (Mortar/paint/tiles)	Low quality	0.967	0.967	0.967
	High quality	1	1	1
Factor A –Components quality				

FACTORS		ASSIGNED VALUE		
		Roof	Tiles	Paint
B1: Method of application	Rough		0.967	0.967
	Standard		1	1
Factor B –Design level				

Table 7.15: Factor E for Surface coatings

FACTORS		ASSIGNED VALUE
E1: Environmental class: atmospheric pollution	Industrial pollution	0.9
	Inland urban environment	1
	Inland rural environment without pollution	1.1
E2:Rain water Exposure frequency	Rainfall zone of average I or II	0.9
	Rainfall zone of average III or IV	1
	Rainfall zone of average V	1.1
E3:Wind exposure level	Wind exposure level V1	0.9
	Wind exposure level V2	1
	Wind exposure level V3	1.1
Factor E – External exposure conditions		

Table 7.16: factor c for Surface components

FACTORS			ASSIGNED VALUE
	YES 1.1	NEUTRAL 1	NO 0.9
C1:Low complexity or risk			
C2:Good quality assurance and inspection routines			
C3:Defined working plan and experienced working designers			
Factor C- WORK EXECUTION LEVEL			

Table 7.17: factor G for Surface coatings

FACTORS		ASSIGNED VALUE
G1: Accessibility to human facilities	There is no easy access for inspection and repair of those humid facilities, that if they have a leak could cause damage to component.	0.9
	There is a partial accessibility for inspection and repair of those humid facilities, that if they have a leak could cause damage to component.	1
	There is total accessibility for inspection and repair of those humid facilities, that if they have a leak could cause damage to component.	1.1
	There is provision in project of mechanism for cleaning	1

Table 7.18: Factor F for surface coating

FACTORS		ASSIGNED VALUE
F1- Exposure to vandalism	Commercial building located in heavy pedestrian traffic area and/or possibility of being vandalized	0.967
	No commercial building located in heavy pedestrian traffic area without possibility of being vandalized	1.00
F2: Vegetation	Vegetation	0.8
	Moss on external surface	0.967
Factor F- Conditions of use		

7.7.4 Metal components

Following tables shows factors for surface coatings. ESTIMATED SERVICE

Table 7.19: factor E for metal components

FACTORS		ASSIGNED VALUE
E1: Environmental class: atmospheric pollution	Industrial pollution	0.9
	Inland urban environment	1
	Inland rural environment without pollution	1.1
E2:Rain water Exposure frequency	Rainfall zone of average I or II	0.9
	Rainfall zone of average III or IV	1
	Rainfall zone of average V	1.1
E3:Wind exposure level	Wind exposure level V1	0.9
	Wind exposure level V2	1
	Wind exposure level V3	1.1
Factor E – External exposure conditions		

Table 7.20: factor a for metal components

FACTORS		ASSIGNED VALUE
A1:Material quality	Corrosion prone (eg. Iron)	0.967
	Anti corrosion	1
A2:Corrosion resistance	Unprotected	0.967
	Protected	1
Factor A –Components quality		

LIFE= Factor E* A* B* C* F* G * Reference service life.

Table 7.21: Factor B for metal components

FACTORS		ASSIGNED VALUE
B1: Fixture design	Not as per standard	0.967
	As per standard	1
Factor B –Design level		

Table 7.22: factor C metal components

FACTORS			ASSIGNED VALUE
	YES 1.1	NEUTRAL 1	NO 0.9
C1:Low complexity or risk			
C2:Good quality assurance and inspection routines			
C3:Defined working plan and experienced working designers			
Factor C- WORK EXECUTION LEVEL			

Table 7.23: factor G metal components

FACTORS		ASSIGNED VALUE
G1: Accessibility to human facilities	There is no easy access for inspection and repair of those humid facilities, that if they have a leak could cause damage to component.	0.9
	There is a partial accessibility for inspection and repair of those humid facilities, that if they have a leak could cause damage to component.	1
	There is total accessibility for inspection and repair of those humid facilities, that if they have a leak could cause damage to component.	1.1
Factor G – Maintenance level		

Table 7.24: factor f metal components

FACTORS		ASSIGNED VALUE
F1- Exposure to vandalism	Commercial building located in heavy pedestrian traffic area and/or possibility of being vandalized	0.967
	No commercial building located in heavy pedestrian traffic area without possibility of being vandalized	1.00
Factor F- Conditions of use		

7.8 Closure

In this section, we have studied about information of factor method and calculation of service life by factor method.

Chapter 8

RESULTS

The condition assessment of the defected components was analyzed and the 'condition index' was evaluated. According to Weibulls Analysis , the weibulls degradation curves were also generated for the same. Service life of the school building components was predicted by using factor method using formulation ESLC= RSLC *A*B*C*E*F*G. Factor A: Quality of the components; Factor B: Design level; Factor C: Work execution level; Factor E: External exposure conditions; Factor F: In-use conditions; Factor G: Maintenance level. From the calculation it can said that, 47.5% of the defected components fall in the range of 0-30%. 9% of defected components fall in the range of 30-60% and 43.5% of defected components fall in the range of 60-100%.

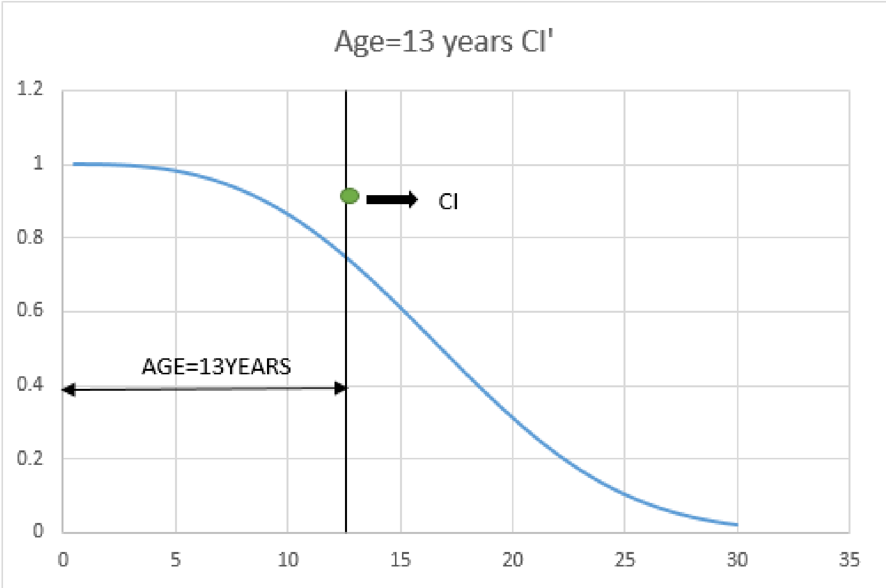


Figure 8.1: Service life of components by factor method

Chapter 9

CONCLUSION

The methodology used in this study consisted of identification of defected areas, followed by evaluation of degradation factor and their influences carried out and the factor method was applied for 30 school buildings of Kolhapur district.

Each defect and failure in every part of the building was significantly appraised and "Condition Index" of individual effect and failure assigned for maximum cases was a factor of 0.9. This was verified by Weibulls analysis. Weibulls curve falls below the standard line i.e below 1 which indicates that the component needs to be replaced. From the calculations, it can be said that 47.5% of defected components fall in the range of 0-30%(excellent condition), 9% of defected components fall in the range of 30-60%(good condition) and 43.5% of defected components fall in the range of 60-100%(Poor condition).By the evaluation of factor method the cumulative service lives of school building components are: a. Brickwork(32 years)

b. Structural Components(41 years)

c. Surface Coatings(20 years)

d. Metal components(31 years)

The above result indicates "surface coating" require a need of immediate repair.

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[8] G. Morcous, "Service life prediction of low slope roof components in building,"

[9] D. Kumar, "Prediction of life cycle expenditure for different categories of council buildings,"

LIST OF PUBLICATIONS ON PRESENT WORK

1.Dige Vaibhavi. 2020. Service life prediction of Zilla parishad school buildings .International Journal o advanced science,engineering and information technology . Ms.no.13533.(In review)

2.Vaibhavi Dige. (2020).Inspection ad service life prediction of ZP school buildings in Shahuwadi region. . International Journal for Research in Applied Science and Engineering Technology. 8. 2321-9653. (Published).

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Inspection and Service Life Prediction of ZP School Buildings in Shahuwadi Region

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***Abstract:** This paper presents a specific case study for estimating the service life of ZP school buildings in the Shahuwadi region of Maharashtra, India. Prediction of building components is evaluated by calculation of 'Condition Indices' followed by the 'Factor method'. For planning maintenance of any building it is necessary to have good information about building components and durability of materials. The construction works have to be maintained during their whole service life. Service life's knowledge becomes very important input data to guide designers, manufacturers and real estate owners in contributing for sustainability of whole building process. The case in consideration was applied to the data collected for a project to assess the condition of 30 schools that belong to selected study area.*
***Keywords:** Service life prediction, school,building maitainance, defects, survey.*

I. INTRODUCTION

The sustainability of building process requires the control and planning of material and economic resources necessary for its life cycle [1]. Design choices should be oriented towards building's components and products characterized by an economically reasonable working life, i.e. which requires economically and materially sustainable maintenance activities, considering the predicted service life [1]. With this aim different researches and standards have been developed at national and international level on durability evaluation. At international level ISO TC 59 SC14 Service Life planning and CIB W80 RILEM Service life prediction methodologies are developing durability evaluation methods to support service life planning [1].

Considerable work has been carried out in the area of service life prediction as requisite tools for helping assess long-term environmental effects, for maintenance management of infrastructure systems, such as roads, bridges, waterways, water distribution and waste-water removal systems, or indeed for maintenance of building envelope systems, envelope components and related materials [2] Increasingly, building material and component manufacturers are seeking systematic methods to assess the likely risk to premature deterioration of existing products given specific climatic effects, or the most vulnerable exposure conditions of new products in specified systems [2].

II. ANALYSIS

1) The current status of secondary education in rural areas is characterized by low enrollment, poor completion rates, poor physical infrastructure, and high drop out. This study will be beneficial to the low income groups of rural areas and it will add to the status of infrastructural facilities of rural education.
2) A good school infrastructure includes with building in good shape including an adequate number of well-organized classrooms, sufficient blackboards, tables, benches, chairs, an adequate number of sanitation facility, laboratory, computer facilities etc.

A. Condition Index

Condition is assessed through visual inspection and hence the repair priorities may differ from person to person based on the individuals' perception, therefore would not be unique. A questionnaire survey is formulated to resolve this issue, for manifestations of various corrosion distresses in RC buildings namely

1) Rusting _rust stains_ and cracks;
2) Delamination/spalling/loss in steel section;
3) Poor workmanship ,honeycombing and moisture marks; and
4) Carbonation and chhorides.

B. Analysis by factor method:

1) *Design Life:* intended service life, expected service life or service life intended by the designer.
2) *Reference Service Life:* service life that a building or parts of a building would expect (or is predicted
3) to have) in a certain set (reference set) of in-use conditions.

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Good luck for your future endeavors

Editor in Chief, iJRASET

INSPECTION AND SERVICE LIFE PREDICTION OF ZP SCHOOL BUILDINGS IN SHAHUWADI REGION

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***Abstract*: This paper presents a specific case study for estimating the service life of ZP school buildings in the Shahuwadi region of Maharashtra, India. Prediction of building components is evaluated by calculation of 'Condition Indices' followed by the 'Factor method'. For planning maintenance of any building it is necessary to have good information about building components and durability of materials. The construction works have to be maintained during their whole service life. Service life's knowledge becomes very important input data to guide designers, manufacturers and real estate owners in contributing for sustainability of whole building process. The case in consideration was applied to the data collected for a project to assess the condition of 30 schools that belong to selected study area.**

Keywords: Service life prediction, school,building maitainance, defects, survey.

I. INTRODUCTION

The sustainability of building process requires the control and planning of material and economic resources necessary for its life cycle [1]. Design choices should be oriented towards building's components and products characterized by an economically reasonable working life, i.e. which requires economically and materially sustainable maintenance activities, considering the predicted service life [1]. With this aim different researches and standards have been developed at national and international level on durability evaluation. At international level ISO TC 59 SC14 Service Life planning and CIB W80 RILEM Service life prediction methodologies are developing durability evaluation methods to support service life planning [1].

Considerable work has been carried out in the area of service life prediction as requisite tools for helping assess long-term environmental effects, for maintenance management of infrastructure systems, such as roads, bridges, waterways, water distribution and waste-water removal systems, or indeed for maintenance of building envelope systems, envelope components and related materials [2]. Increasingly, building material and component manufacturers are seeking systematic methods to assess the likely risk to premature deterioration of existing products given specific climatic effects, or the most vulnerable exposure conditions of new products in specified systems [2].

II. ANALYSIS

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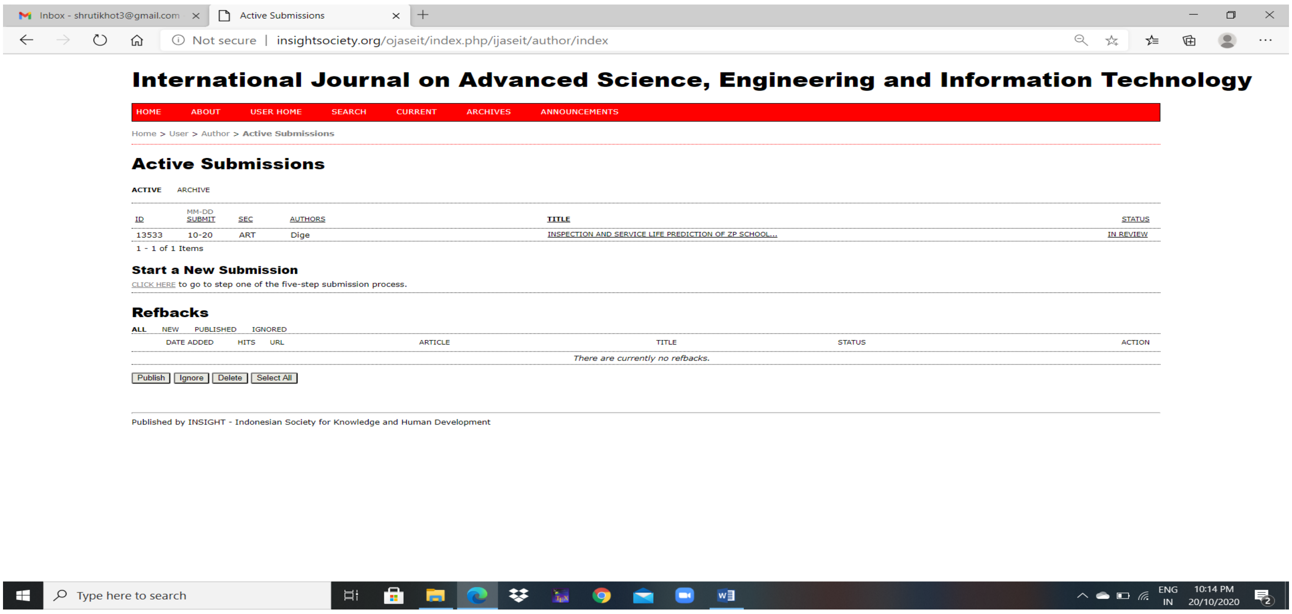
- A good school infrastructure includes with building in good shape including an adequate number of well-organized classrooms, sufficient blackboards, tables, benches, chairs, an adequate number of sanitation facility, laboratory, computer facilities etc.
- *CONDITION INDEX*

Condition is assessed through visual inspection and hence the repair priorities may differ from person to person based on the individuals' perception, therefore would not be unique. A questionnaire survey is formulated to resolve this issue, for manifestations of various corrosion distresses in RC buildings namely

1. Rusting _rust stains_ and cracks;
2. Delamination/spalling/loss in steel section;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SYNOPSIS OF M. TECH DISSERTATION

1. Name of Program : Civil Construction Management

2. Name of Student : Vaibhavi Ravindra Dige

3. Date of Registration : July 2019

4. Name of Guide : Prof. D. S. Patil

5. Sponsors Details : No

6. Proposed Title : Service life prediction of ZP school buildings.

7. Synopsis Dissertation Work

7.1 Relevance

A building is not a piece of transportation that by its use you can say it wears down. A building is different and it is really a part of a landscape. It becomes part of the city, of the treasury of the spaces of the city.Thus lifetime perspectives in construction must consider 'true' historical dimensions including-how performative needs may change overtime, and how the act of building becomes rooted in civilization.

7.2 Introduction

The sustainability of building process requires the control and planning of material and economic resources necessary for its life cycle. Design choices should be oriented towards building's components and products characterized by an economically reasonable working life, i.e. which requires economically and materially sustainable maintenance activities, considering the predicted service life.

With this aim different researches and standards have been developed at national and international level on durability evaluation. At international level ISO TC 59 SC14 Service Life planning and CIB W80 RILEM Service life prediction methodologies are developing durability evaluation methods to support service life planning.

Considerable work has been carried out in the area of service life prediction as requisite tools for helping assess long-term environmental effects, for maintenance management of infrastructure systems, such as roads, bridges, waterways, water distribution and waste-water removal systems, or indeed for maintenance of building envelope systems, envelope components and related materials. Increasingly, building material and component manufacturers are seeking systematic methods to assess the likely risk to premature deterioration of existing products given specific climatic effects, or the most vulnerable exposure conditions of new products in specified systems.

7.3 Review of the literature

7.3.1. Mark Alexander, Hans Beushausen (2019), "Durability, service life prediction, and modelling for reinforced concrete".

Ever increasing attention is being paid to deterioration prediction and service life modelling of reinforced concrete structures. Research has progressed to a stage where service life models and design philosophies are, to varying degrees, included in some codes and standards, such as the fib Model Codes and ISO 13823. This has helped to base practical durability design on sound engineering approaches. This paper reviews service life modelling and prediction, and service life design, covering limit state design philosophies and deterioration models. An overview on recent developments, and a critical review on common assumptions in service life modelling and on the application and limitations of the various approaches, are presented. It is emphasized that design approaches and models need to be validated with field observations. It is argued that a performance-based approach is the most suitable engineering tool for durability design.

7.3.2. Karim El-Dash (May 2011), "Service Life Prediction for Buildings Exposed to Severe Weather".

This paper presents a specific case study for estimating the service life of public buildings in the harsh weather of Kuwait using the factor method. Estimating the service life helps enhance the sustainability of these buildings and controls some economic aspects. The case in consideration was applied to the data collected for a project to assess the structural behavior of twenty-six buildings that belong to Kuwait University. The buildings were assessed by visual inspection, material testing, and structural analysis. The findings of these investigations guided the working team to assign the values of the different factors used in the prediction process. The factors were predicted in a probabilistic approach to consider the inherent variability in the construction components and the surrounding effects. The results of the service life prediction provide a perspective for the expected life span of buildings in similar conditions.

7.3.3. Yasuhiro Mori P and Bruce R. Ellingwood (1993), Reliability-based service-life assessment of aging concrete structures".

Concrete structures may be affected by aging or changes in strength and stiffness beyond the baseline conditions assumed for design. These changes may impair the safety and serviceability of the structure, and should be considered as part of the process by which a structure is evaluated for continued future service. Methods are being developed using structural reliability principles to evaluate timedependent reliability of reinforced or prestressed concrete structures. These methods enable the impact on safety and serviceability of uncertainties in loading conditions,structural strength, and strength degradation due to aggressive environmental stressors to be assessed qualitatively. A probability-based method to evaluate time-dependent reliability of components and systems was presented, and the sensitivity of the reliability to various parameters describing load occurrence and strength degradation was illustrated using simple examples.

7.3.4. Sotiris Demisa, Vagelis G. Papadakis (2019), "Durability design process of reinforced concrete structures - Service life estimation, problems and perspectives".

The need for a structured durability design process of reinforced concrete elements is strongly emphasized in the current study. Under such a framework, concrete service life estimation tools (SLTs) can be vital aids. Their utilization however is not an easy process and might lead to confusing results for the same element under the same harsh environment, as it is presented via a case study in this work. The reasons for such a behavior are explained and the next steps and research actions that have to be taken in establishing a widely accepted durability design process are discussed.

7.3.5. B. Martín-Pérez and Z. Lounis (JAN 2003), "Numerical modelling of service life of reinforced concrete structures".

This paper presents an approach for service life prediction of reinforced concrete structures exposed to chloride environments that combines a finite element modeling of the chloride transport and a reliability-based analytical model for onset of damage and its accumulation. Service life is defined as the time until damage accumulation reaches an unacceptable level or 'limit state'By using Monte Carlo simulation, the probabilistic distributions of the chloride penetration front and corrosion initiation time are generated. The proposed approach is illustrated on a reinforced concrete bridge deck exposed to chlorides from de-icing salts.

7.3.6. Johann Mc Duling , Emile Horak , Chris Cloete (2008), 'Service Life Prediction Beyond the 'Factor Method''.

The current 'state of the art' Factor Method [ISO 15686-1:2000] for service life prediction calculates an estimated service life, but not changes in condition.The application of the stochastic Markov Chain is restricted by limited availability of historic performance data on degradation of building materials required to populate transition probability matrices.This paper, based on a PhD thesis, looks at the application of neuro-fuzzy artificial intelligence to translate expert knowledge into probability values to supplement historic performance data for the development of Markovian transitional probability matrices, towards prediction of service life, condition changes over time, and effects of maintenance levels on service life of buildings.

7.3.7. G. HED (1999), "Service life planning of building components".

The study was connected to a demonstration construction scheme and was integrated in the design and construction of a building. The study was performed in accordance with the draft standard ISO/DIS 15686.1 Buildings: Service life planning, and one aim was to test, evaluate and give input to further development of the standard. This paper will discuss this approach and discuss how available service life data can be collected and evaluated. Examples of service-life predictions are also shown.

7.3.8. G Morcous and H Rivard (2006) "Service life prediction of low slope roof components in building".

This paper presents the development of probabilistic models for the service life prediction of low-slope roof components (i.e. membrane and flashing). Data use for model development are collected within the Building Envelope Life Cycle Asset Management (BELCAM) research project. The parameters that significantly affect the deterioration of built-up roof (BUR) membrane and flashing are identified through statistical tests (i.e. correlation analysis and ANOVA). Transition probability matrices of Markov-chain deterioration models are developed to be used in predicting the future condition of roof components.

7.3.9.Dhirendra Kumar, Sujeeva Setunge and Indubhushan Patnaikuni(2010), "Prediction of life cycle expenditure for different categories of council buildings."

ISO presents a valuable methodology based on the factor method in the area of service life estimation but it requires considerable local knowledge about degradation of components and materials. The factor method on the other hand is fairly simple but identifies the main parameters influencing service life. The result, however, is only a single figure for service life and does not take into account the variability of the processes involved. A lot of work is being done in the area of service life prediction, but there is very little that can be readily used by building asset managers. Hence, there is a great need to develop a simple model which can be easily calibrated and used. The model proposed here can be easily implemented by practitioners and would be of benefit to infrastructure managers of city councils.

7.4 Research Gap

The research papers studied showed that the experimental study done previously was using 'Limit performance method', Life365, Eucon, Duracon, Factor method software, were time consuming and costly. Whereas the study of service life prediction will be analyzed using

'Statistical package for social sciences (SPSS)' which may be time consuming and economical method.

7.5 Problem Statement

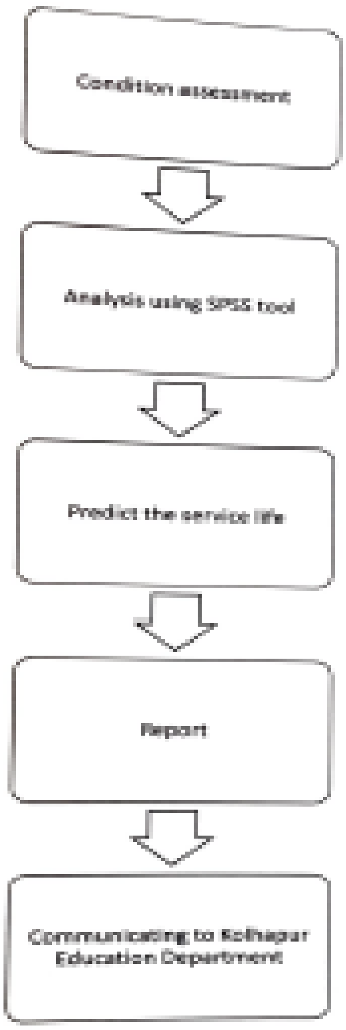
The structural health of the old constructions goes on depleting after consecutive years. The environmental conditions adversely affects the old buildings and the human health. Thus it is important to know the service life of building for its repair and maintenance.

7.6 Objectives

- Perform condition assessment of ZP school buildings.
- Analyze the survey data and predict service life of ZP school buildings.
- Prepare a report and communicate the research results to Kolhapur Education Department.

7.7 Methodology:

SPSS is revolutionary software mainly used by research scientists which help them process critical data in simple steps. These techniques are used to analyze, transform, and produce a characteristic pattern between different data variables. In addition to it, the output can be obtained through graphical representation so that a user can easily understand the result.


Condition assessment
Analysis using SPSS tool
Predict the service life
Report
Communicating to Kolhapur Education Department

7.6 Plan of Proposed Work

- **Phase1-(July-September)**
  - Literature Review
  - Problem Identification
  - Research Gap Analysis
  - Scope of Work & Objectives
- **Phase 2-(October- December)**
  - Collecting data about the building
  - Assessment of the desired building -BY USING FACTOR METHOD
- **Phase 3-(January-March)**
  - Analysis by SPSS statistics
  - Summary of experimental results.
- **Phase 4-(April-May)**
  - Conclusions
  - Report writing

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Dhirendra Kumar, Sujeeeva Setunge and Indubhushan Patnaikuni(2010). "Prediction of life cycle expenditure for different categories of council buildings." Journal of performance of constructed facilities © asce / november/december 2010 / 561

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Sotiris Demisa, Vagelis G. Papadakis (2019), "Durability design process of reinforced concrete structures - Service life estimation, problems and perspectives". Journal of Building Engineering 26 (2019) 100876

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Date- / / 2019
Place – RIT, Rajaramnagar

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Project report

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SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Sotiris Demis, Vagelis G. Papadakis. "Durability design process of reinforced concrete structures - Service life estimation, problems and perspectives", Journal of Building Engineering, 2019 Publication	2%
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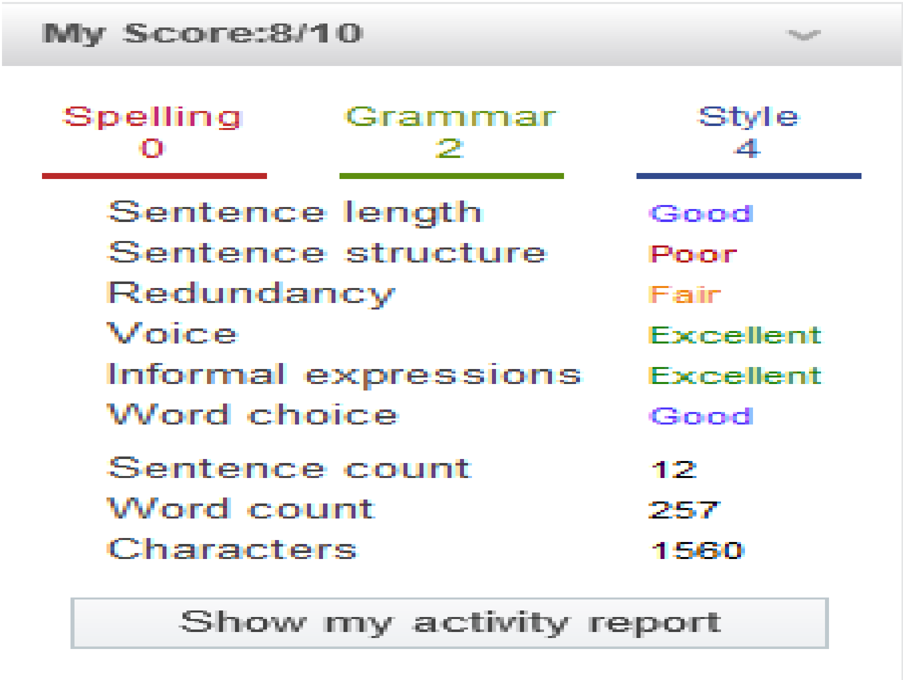

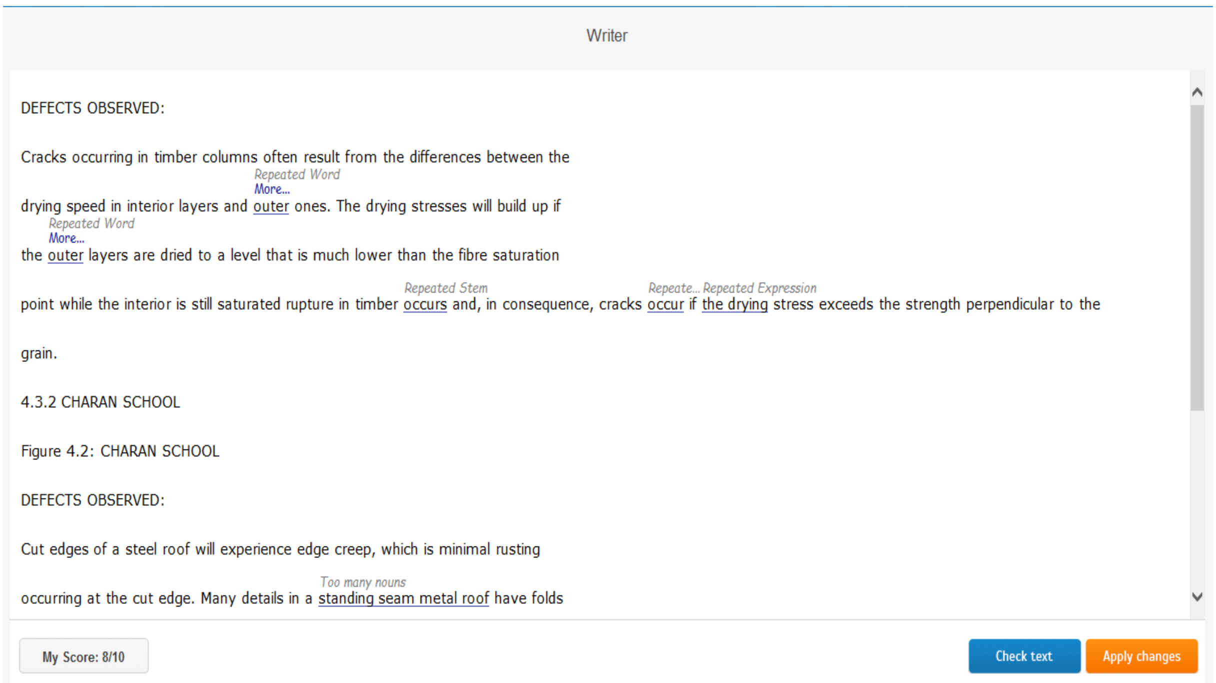

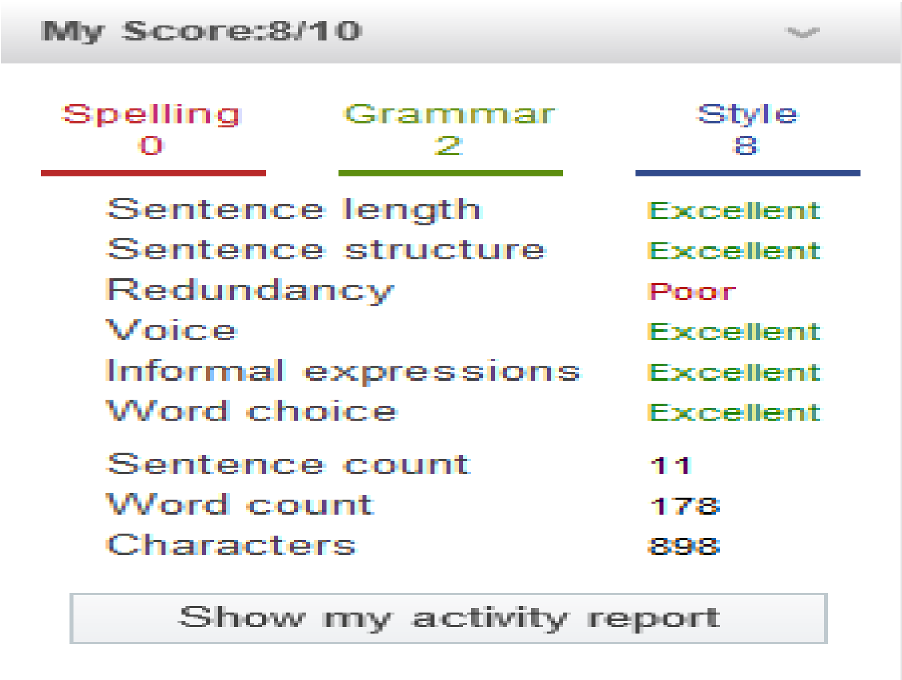
My Score:8/10
Spelling
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Sentence length
Excellent
Sentence structure
Excellent
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Excellent
Informal expressions
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11
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Characters
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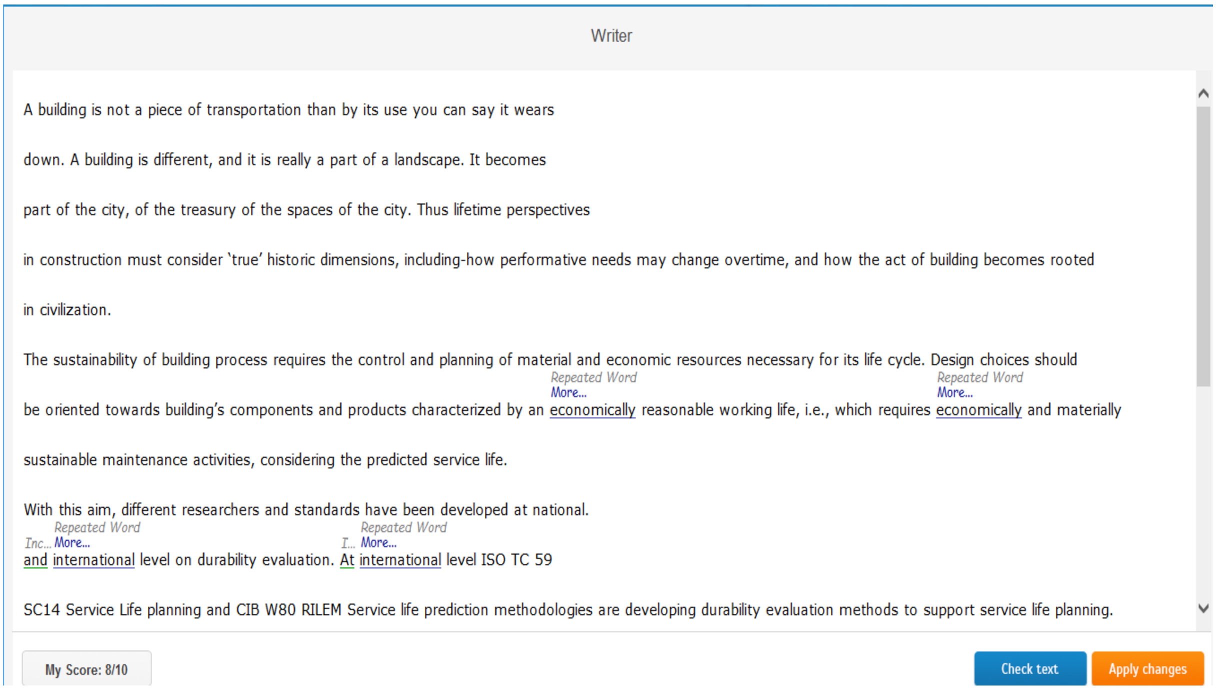
Writer
A building is not a piece of transportation than by its use you can say it wears
down. A building is different, and it is really a part of a landscape. It becomes
part of the city, of the treasury of the spaces of the city. Thus lifetime perspectives
in construction must consider 'true' historic dimensions, including-how performative needs may change overtime, and how the act of building becomes rooted
in civilization.
The sustainability of building process requires the control and planning of material and economic resources necessary for its life cycle. Design choices should
Repeated Word
More...
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be oriented towards building's components and products characterized by an economically reasonable working life, i.e., which requires economically and materially
sustainable maintenance activities, considering the predicted service life.
With this aim, different researchers and standards have been developed at national.
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and international level on durability evaluation. At international level ISO TC 59
SC14 Service Life planning and CIB W80 RILEM Service life prediction methodologies are developing durability evaluation methods to support service life planning.
My Score: 8/10
Check text
Apply changes

VITAE

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