

# Building Component Degradation Analysis using FMEA

Jadhav Suhas S.<sup>1</sup>, Patil Dhananjay S.<sup>2</sup>

<sup>1</sup>P.G.Scholar, Department of Civil Engineering, Rajarambapu Institute Of Technology, Islampur, Maharashtra, India

<sup>2</sup>HOP Construction Management, Rajarambapu Institute of Technology, Islampur, Maharashtra, India

**Abstract:** Construction industry in India is booming with new projects coming in, growth in GDP and so on; but on other hand, neglecting the existing assets and not maintaining them to appropriate serviceability, this may be due to negligence or unavailability of funds or insufficient literacy about component degradation. The degradation of building components occur due to various factors as physical, chemical and environmental actions. These factors degrade building components over the life of the structure reducing serviceability. In order to maintain the building component in serviceable condition it is necessary to study the degradation process and root causes. This study utilizes; the "Failure Mode Effect Analysis" method to find out the possible failure modes and their causes as well as effects. In this study eight buildings at an interval of three years were selected and components were studied to find out causes and their effects, through the analysis the event driven graphs for these components are plotted, which will help understand the failure process of building components.

**Keywords:** Degradation, FMEA, Event Driven Graph, Failure Modes, Failure Causes, Effects, Degradation Scenario Block Diagram

## 1. Introduction

The need of analyzing the deterioration of the building structure and building component is very important. The current scenario shows that Construction of new facilities is booming neglecting the existing which if properly have maintained, may have served many more Year's. The negligence in maintaining an old / existing building is a result of; non availability of funds and one main reason also is insufficient literacy of component degradation. "The degradation of building materials is defined as the gradual, spontaneous, slow process in which the material losses its own characteristic properties due to various Physical, Chemical and Environmental action" [8]. There are lots of factors which affects the degradation of the building components. "Degradation factors or agents can be defined as any of the group of factors that can affect the performance of a building material, component or system" [8]. These factors are classified according to their nature like mechanical, chemical, physical, biological, and environmental. "The degradation mechanism of the building materials is defined as the sequence of chemical, mechanical or physical changes that lead to detrimental changes in one or more properties of the building material when exposed to one or more degradation factors" [8].

## 2. Failure Mode Effect Analysis

The Failure Mode Effect Analysis method is used for finding out different failure modes, their causes and their direct and indirect effects on building components. The Failure Mode Effect Analysis method was developed in 1970<sup>[2]</sup> for Industrial domain and now days it is used in Building domain for finding possible degradation scenarios. The proposed method consists of four parts<sup>[2]</sup>

- System analysis
- Qualitative analysis
- Quantitative analysis
- Graphical representation of Quantitative Analysis.

The system analysis contains of three steps a. Structural analysis, b. functional analysis and c. process analysis<sup>[2]</sup>. The structural analysis consists of the decomposition of products into components. The functional analysis consists the function ensured by the each component. The process analysis is to determine all the errors, defects, and damages that can occur during the construction process. The quantitative analysis is to determine the behavior of product in service life. The data from the quantitative analysis is capitalized in FMEA table that contain the Function, Component, Mode, Causes and their Direct Effects and Indirect Effects.

**Table 1:** Failure Mode Effect Analysis

Function	Component	Mode	Causes	Direct Effects	Indirect Effects
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The results from quantitative analysis are plot in graphical form like Event Driven Graph. The Event Driven Graph consists of three stages Initial Stage, Degradation Stage and Final Stage. This graph shows the entire degradation process or it gives the process of degradation. In this graph the time factor is not considered.

## 3. Case Study

In order to evaluate failure modes and degradation scenarios 2 components External Plaster and Internal Plaster are considered, for case study Eight buildings at an interval of three years are selected. Data in the form of general information types of defect, maintenance was collected to analyze failure modes and effects.

## 4. Failure Mode Effect Analysis for Plaster

The system analysis for Plaster contains three steps

- 1) Structural analysis for Plaster- The plaster is a part of component contains three a. Brick Masonry, b. Mortar, c. Paint.

- 2) Functional analysis for Plaster-The functional analysis is nothing but the functions ensured by each components. a. Functions of Brick Masonry- Load transfer and Partition Purpose, b. Function of Mortar- Decorative and Protection to interior material, c. Function of Paint- Decorative and Protection to interior material.
- 3) Process analysis- The process analysis is to determine all the errors, defects, damages, degradation that could occur to the product during its construction process. Following are the process defects in Plaster. a. Poor quality of materials, b. Bad Workmanship, c. Rich mix of mortar, d. Less thickness of plaster, e. Faulty construction, f. Improper curing of Plaster.

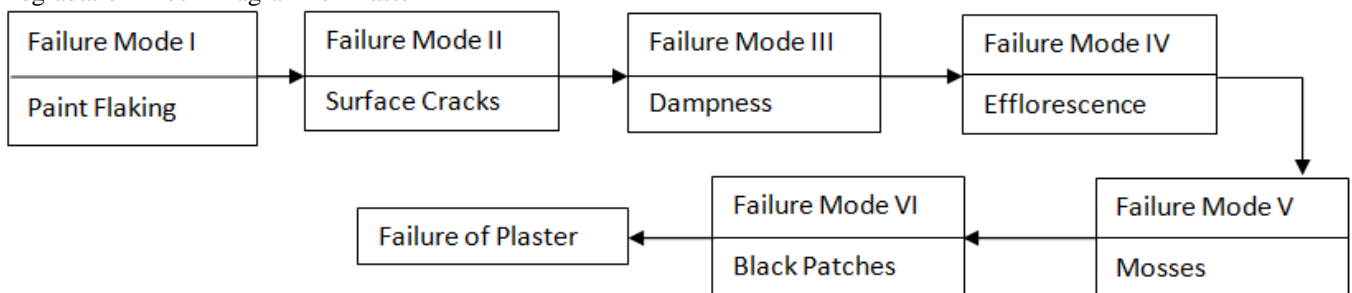
#### For External Plaster:

1. Surface Cracks
2. Dampness
3. Paint Flaking
4. Efflorescence
5. Mosses
6. Black Patches
7. Expansion

#### 4.1. Data Collection

Data collected through eight building was studied and overall of failure modes were observed to represent both the components. Various defects found and coupled from all these 8 buildings are as follows;

Degradation Block Diagram for Plaster



**Table 2:** Failure Mode Effect Analysis for External Plaster

Failure Mode Effect Analysis					
Function	Component	Mode	Causes	Direct Effect	Indirect Effect
Decorative and Protection to Interior Materials	Paint	Hair line Cracks	Cracks in Mortar	Cracks in Paint Film	Percolation of Moisture
			Variation in Temperature and Moisture <sup>[5]</sup>		
		Lifting	Moisture	Debonding of Paint Film	Exert Pressure on Bond
		Blistering	Moisture <sup>[5]</sup>	Small Bubbles Occurs on Paint	
			Lack of Bond <sup>[5]</sup>		
Decorative and Protective to Interior Materials	Mortar	Flaking	Moisture <sup>[5]</sup>	Paint Flak	Bad Aesthetic view
			Freeze and thaw action		
			Shrinkage <sup>[4]</sup>		
			Moisture Change <sup>[4]</sup>		
			Growth of vegetation		
		Surface Cracks	Thermal Expansion and Contraction <sup>[4]</sup>	Surface Cracks	Percolation of Moisture
			Poor quality of Maintenance		Cracks width increases
			Moisture in Mortar		Crack width increases
			Leakage of water from Sewer Pipes <sup>[6]</sup>		
			Faulty Maintenance of Joint <sup>[6]</sup>	Dampness	Crack Width increases
		Dampness	Leakage of water from Bath and Toilet		Water Percolation on Mortar
			Rain Water		
			Temperature <sup>[3]</sup>	Small White Patches	Bad appearance of Plaster
		Efflorescence	Moisture in Mortar <sup>[3]</sup>		
			Salts <sup>[3]</sup>		
		Mosses	Water from Roof	Mosses Production on Mortar	Bad Aesthetic view
			Leakage of water from Bath and Toilet Block		
			Humidity in mortar		
			Temp or Heat		
			Bacteria		
		Blacks	Moisture	Black Patch	Bad appearance of

		Patches	Temperature	Plaster Falls	Plaster
		Expansion	Poor Quality of Work <sup>[4]</sup>		
			Weak mix of Mortar		
			Rich Mix of Mortar		
			Moisture <sup>[4]</sup>		
			Weak Bond <sup>[4]</sup>		
Load Transfer and	Brick Masonry	Dampness	Moisture from Septic Tank	Dampness in Masonry	Helps to Form the Efflorescence, Mosses
			Water from Bath		
		Cracks	Plant Growth in Plaster	Cracks	

Table No 2 shows the Failure Mode Effect Analysis for External Plaster. The table shows the various failure modes of External Plaster and there causes and the direct and indirect effects of that cause the defects in External Plaster.

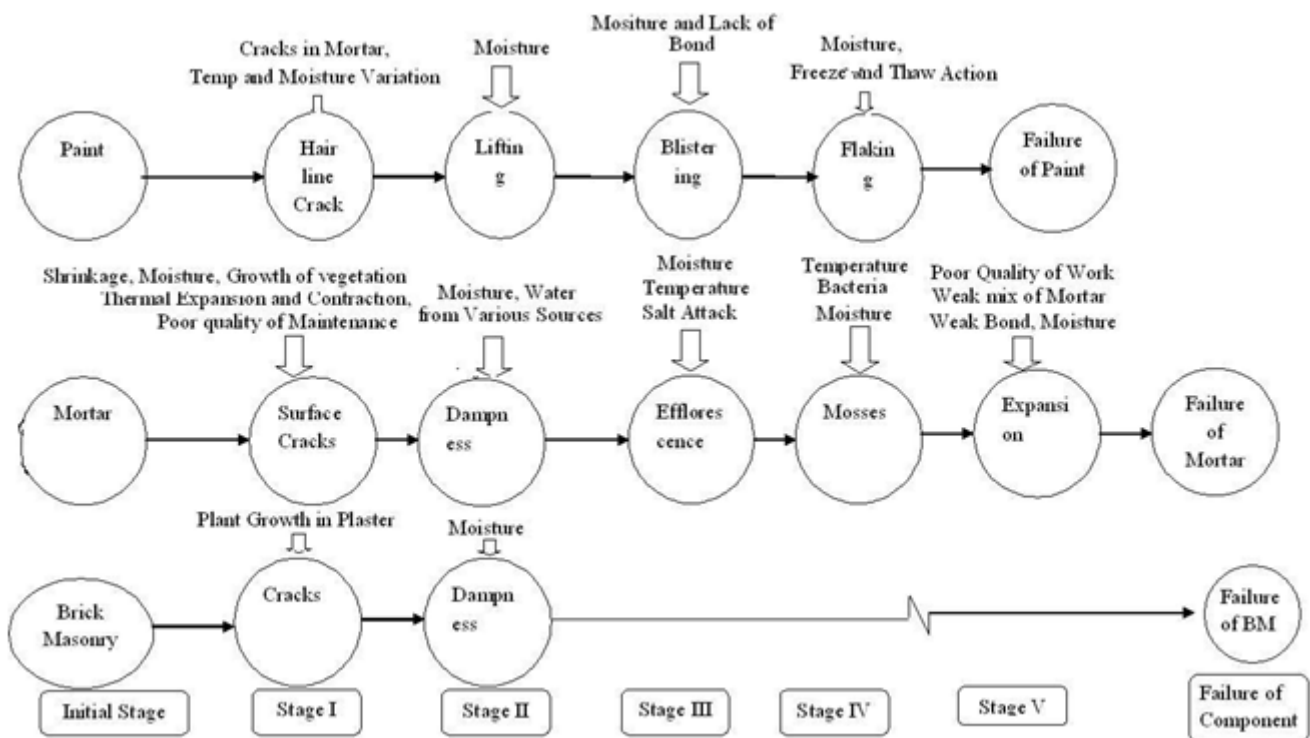


Figure 1: Event Driven Graph for External Plaster <sup>[2]</sup>

The above figure shows that the process of degradation and various causes for failure modes of External Plaster. The sequence of failure for paint was Hair Line Cracks, Lifting, Blistering and Flaking. The sequence of failure for mortar was Surface Cracks, Dampness, Efflorescence, Mosses and Expansion. The sequence of failure for Brick Masonry was cracks and Dampness

#### For Internal Plaster:

1. Surface Cracks
2. Dampness
3. Paint Flaking
4. Efflorescence
5. Mosses

Table 3: Failure Mode Effect Analysis for Internal Plaster

Failure Mode Effect Analysis					
Function	Component	Mode	Causes	Direct Effect	Indirect Effect
Decorative and Protection to Interior Materials	Paint	Hair line Cracks	Cracks in Mortar <sup>[5]</sup>	Cracks in Paint Film	Percolation of Moisture
			Variation in Temperature and Moisture		
		Lifting	Moisture <sup>[5]</sup>	Debonding of Paint Film	Exert Pressure on Bond
		Blistering	Moisture <sup>[5]</sup>	Small Bubbles Occurs on Paint	
			Lack of Bond <sup>[5]</sup>		
Decorative and Protection to Interior Materials	Mortar	Flaking	Moisture	Paint Flak	Bad Aesthetic View
			Freeze and thaw action		
		Surface Cracks	Moisture	Surface Cracks	Dampness
			Thermal Expansion and Contraction in Joints <sup>[4]</sup>		
			Faulty Construction Joint		
			Defective External Plaster <sup>[4]</sup>		Moisture enters in Mortar
			Lack of Maintenance <sup>[4]</sup>		

			Poor Quality of Work		
			Shrinkage <sup>[4]</sup>		
		Dampness	Water from Roof	Dampness	Increases the Crack Width, Helps to generation of Mosses, Efflorescence and, Bad Aesthetic View
			Water from Construction joint		
			Moisture in Masonry <sup>[6]</sup>		
			Water from OTS		
			Poor Quality of Work <sup>[6]</sup>		
			Bad Workmanship		
		Efflorescence	Temperature or Heat <sup>[3]</sup>	Small White Patches	Bad Aesthetic View
			Moisture in Mortar <sup>[3]</sup>		
			Salts <sup>[3]</sup>		
		Mosses	Moisture in Mortar	Mosses	Bad Aesthetic View
			Temperature change		
			Humidity in Rooms		
			Bacteria or Fungi		
Load Transfer and Partition Purpose	Brick Masonry	Cracks	Defective External Plaster	Water percolates	Water percolation
		Dampness	Moisture	Dampness in Plaster	Increase Dampness in Mortar

Table No 3 shows the Failure Mode Effect Analysis for Internal Plaster. The table shows the various failure modes of Internal Plaster and there causes and the direct and indirect effects of that cause the defects in Internal Plaster.

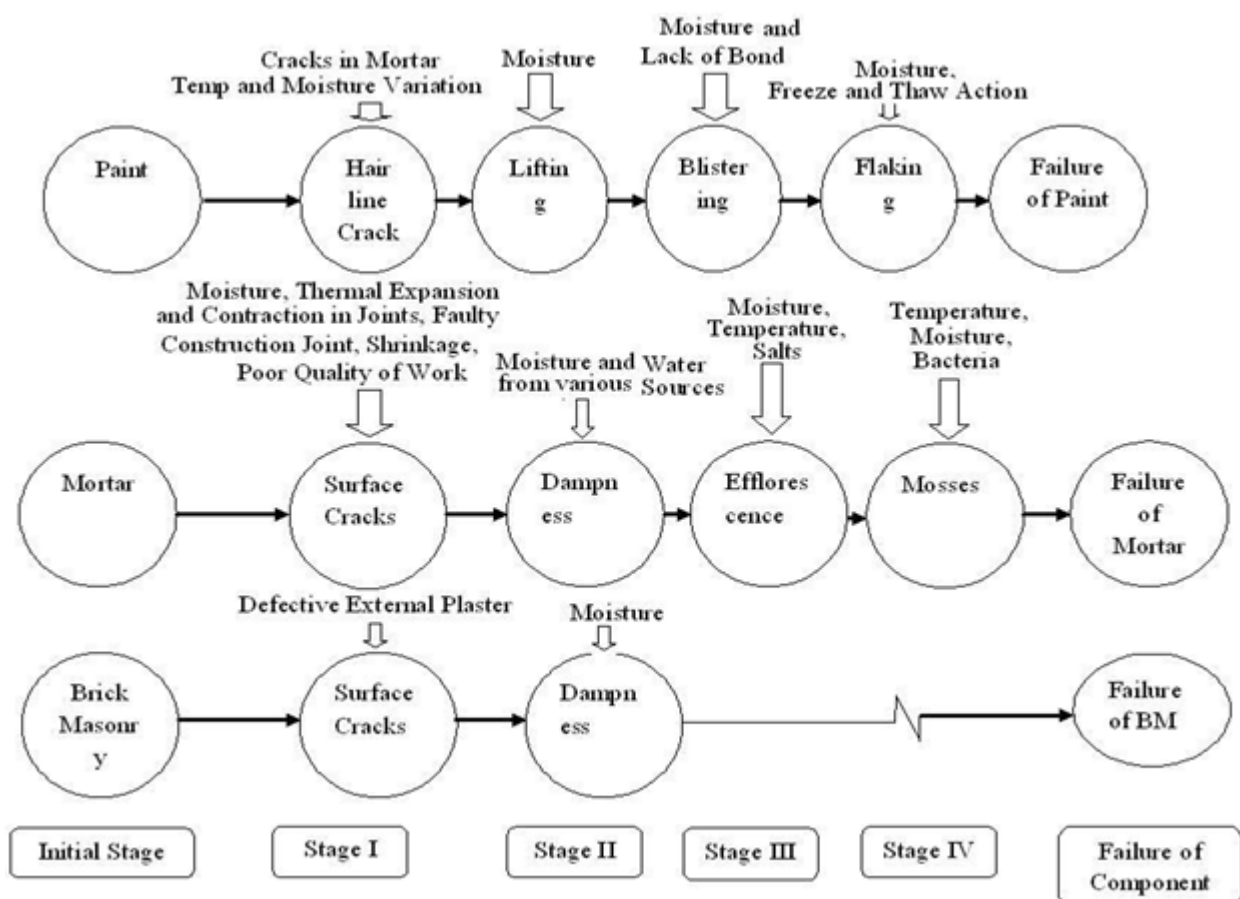


Figure 2: Event Driven Graph for Internal Plaster<sup>[2]</sup>

The above figure shows that the process of degradation and various causes for failure modes of Internal Plaster. The sequence of failure for paint was Hairline Cracks, Lifting, Blistering and Flaking. The sequence for failure of Mortar was Surface Cracks, Dampness, Efflorescence and Mosses.

The sequence of failure for brick masonry was Cracks and Dampness.

## 5. Conclusion

From above study the following conclusions are derived

- 1) After inspection of the case studies following failure modes were observed in External and Internal Plaster Surface Cracks, Efflorescence, Dampness, Mosses, Black Patches, Paint Flaking and Expansion.
- 2) After doing Failure Mode Effect Analysis following major defects and their causes were observed
  - a) Surface Cracks are occurs regularly on the plaster. When cracks occur immediately after construction they are due to shrinkage in cement. There are also causes for surface cracks like moisture in mortar, unwanted growth of vegetation on plaster. The thermal expansion and contraction is also causes the cracks.
  - b) Dampness is also major defect in plaster. The causes of dampness are moisture and water percolation through sewer pipes and rain water pipes.
  - c) Mosses is also major defect in plaster occurs near the sewer pipes due to the moisture, temperature and various biological agents such as fungi and algae.
  - d) The causes of paint flaking are moisture, freeze and thaw action and lack of bond between mortar and paint.

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