

International Journal of Innovative Research in Science, Engineering and Technology

(A High Impact Factor, Monthly, Peer Reviewed Journal)

Visit: www.ijirset.com

Vol. 7, Issue 12, December 2018

Facade Failure Trends Analysis in High Rise Buildings during Construction Phase in Jakarta

Wildan Muadz Effendi¹, Oei Fuk Jin²

Master Student of Civil Engineering, Tarumanagara University, Jakarta, Indonesia¹

Master Lecturer of Construction Management, Tarumanagara University, Jakarta, Indonesia²

ABSTRACT: Façade is an architectural element that ranks art on a building. In addition, architecturally, the façade has a protective function against the occupants of the building inside. If there is strong performance in the building, namely the performance of protection from leakage, performance and safety of energy, there are no functions needed from the outside. Failure of the façade function is the installation of one of the four main functions that cannot be achieved. Minimizing errors when work has been done is ineffective. Referring to PMBOK (Project Management Body of Knowledge), the quality of management must be clearly defined at the time of planning, adjusted to the quality and standard requirements that apply. This study analyze the processes that occur in the construction process and is not described planning phase.

KEYWORDS: Facade, Failure, Quality, PMBOK, Performance

I. INTRODUCTION

As a international standart project management, the PMBOK Guide the project quality management must be focus on the stages of planning, development, and management of environmental quality enable the project to achieve or exceed of all stakeholders needs or expectations. All activities that determine the quality policy, goals and responsibilities of the project are to meet the expected needs.

In PMBOK Chapter 8 describes about three main processes related to quality management that are intended. The first is the quality management plan, which is identifying quality and standard needs and how to fulfill these standards and quality needs. The second is perform quality assurance, which is to audit quality requirements and carry out quality control measurements to ensure the right quality standards are used. Third is control quality, which is monitoring work results to assess performance results and provide input if work results are found to be incompatible.

Indonesian Statistic Central Agencies, called BPS (*Badan Pusat Statistik*) said that the facade industry in Indonesia experienced ups and downs along with the development of the facade industry in Indonesia. After the economic crisis hit the country in 1998, many facade specialist contractors were unable to survive. Likewise facade technology in Indonesia, has not experienced many developments. But even though the development of facade technology is relatively slow, facade failure still occurs and recurs in the same way, no improve from specialist contractor.

II. LITERATURE REVIEW

Moghtadernejad (2014) in his research entitled Service Life Safety and Reliability of Building Facades, stated Benchmark of failure in the building façade divided into seven parameters, that is: workmanship, Design, Supervision, Fabrication, Detailing Engineering, Materials and Low Maintenance. However, because the review of this study is a building during the construction phase, the Low Maintenance parameters are not included in the discussion parameters. The following describes the supporting literature on the perimeter of failure that will be used in this study.

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a. Design

Timothy A Soebroto (1999) in his research entitled Analysis of Curtain Wall in the BI Renovation Project, stated that at the design stage of the building closure system, there are several basic criteria that are mutually bound to one another. The criteria that must be met in the design of the façade system are: Environmental criteria, structural criteria, cost criteria, regulatory criteria, aesthetic criteria and implementation criteria. Potential failure of the façade performance can occur in each design criterion. The Whole Building Design Guide (WBDG-2016), states that potential failures that must be considered are related to the performance of the façade during the Durability and service life expectancy stages. Includes: Movement of the facade (movement); Drainage system; material degradation.

b. Details Engineering

The Whole Building Design Guide (WBDG-2016), states that the potential failure that must be considered regarding the performance of the façade during the detailed engineering stage is to include Details on each spandrel connection and vision in a typical floor area. Includes: Splice joint on the transom, heater release on the spandrel area, perimeter sealant joint, metal sill flashing, curtain wall head. Ending curtain wall. Includes: detailed installation of flashing, protection of curtain walls through flashing, water barrier, frame curtain wall. Includes connection system, connection details and reliability of air and water penetration, Curtain wall sill. Includes details on the installation of flashing that should not be interrupted, Intermediate mullion, Unit stack joint includes the detail joint on the curtain wall frame. Sealant receiver details. Water seal, water seal and block setting.

c. Supervision

Rajand Govin (2015) said that the description of the failure of the façade due to supervision was the absence of a monitoring checklist in the field to ensure that the work plan and project quality plan were met. Weak coordination and weak management of the placement of materials in the field that damage material quality also become a failure of the façade that can be grouped into parameter supervision.

d. Workmanship

The next failure parameter façade is failure due to weak labour or workmanship. Dwanso Humprey (2014) said that failure due to workmanship was still the main issue where causing failure of buildings during construction. The lack of skilled workers in facade workers defined by certification and experience, and the lack of care of workers in the field contributed to failures in the construction world including the failure of the façade.

e. Material

The failure of the façade's performance is also inseparable from the failure of material determination. The façade industry association where initiated by Bath University in the United Kingdom, the Center of Window and Cladding Technology (CWCT-2001) has issued a handbook. In the CWCT handbook there is stated that the use of the wrong material can be a failure for the façade. The use of non bleed and non-stain sealant materials on aluminium composite panel (ACP) joints, using a backer rod at each sealant connection, the use of block settings with material made from chloroprene rubber or EPDM with a minimum hardness of 90 degrees is the determination of material to be obeyed to avoid failure material consequences.

f. Fabrication

The last parameter mentioned by reference as a façade failure is failure due to fabrication. The LP2FI (Indonesian Façade Education and Training Institute - 2017) mentions in its education module that the most frequent failures at the fabrication stage are profile tolerances including thickness profiles in fabrication, solid profiles, profile lengths, profile angles, profile straightness and weep hole. Tolerance at this fabrication stage will result in greater problems in the field, for example tolerating the length of the fabricated profile will result the gaps in the field which can facilitate the concentration of water and causing leakage.

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III. RESEARCH METHODOLOGY

Research Process

The analysis process in this study was carried out by grouping trends in facade failure findings in each project using a simple trend principle analysis, namely the Pareto principle, then validating the findings of problem trends using FMEA analysis (Failure Mode Effects Analysis).

The study was conducted by surveying nine ongoing projects on the façade work. Starting from shop drawing evaluation, evaluating field installation methods, and performance tests (spray tests). Then the problem findings are grouping into six variables according to the parameters mentioned by Moghtadernejad on his paper.

The grouping of each failure in the review project of the parameters discussed is explained in the following table 1.

Table 1. Parameter Description Table

	Description	Source	Case
Detail Enginnering	Facade Failure caused of detail engineering	WBDG-UK (2016)	Setting Block, Shim Receiver, Sealant pad,
Design	Facade Failure caused of design failure's	WBDG-UK (2016)	Weeped Hole, Supporting curtain wall,
Supervision	Facade Failure caused of site supervision	Iber-Lepenc (2008)	Checklist process, Methode Statement
Workmanship	Facade Failure caused of unskilled labour	Poor workmanship in construction (2014)	Sealant space grouting
Material	Facade Failure caused of wrong materialdefinition	CWCT Handbook (2001)	<i>staining sealant</i> on cladding joint
Fabrication	Facade Failure caused of fabrication.	LP2FI Handbook (2017)	The size of the facade frame profile is too small

The first method to Resolve Research Problem: Problem Trends (Pareto Principles)

Pareto principle's states that for many events, about 80% of the effect is caused by 20% of the causes. The variables used in the pareto analysis are variables with the descriptions described above.

The first step in this study is the grouping of findings problems from field observations on the failure parameters described earlier. The findings of the problems that have been grouped according to the parameters that have been put forward are then made into the pareto diagram.

The second method is to determine the highest failure contributors to the façade during the construction period based on the results of the pareto groupings that have been carried out.

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Failure Mode Effect Analysis (FMEA)

There are many approach methods in evaluating the quality of a product. Failure Mode Effect Analysis (FMEA), is a method that aims to enable organizations to anticipate failures during the design phase by identifying all possible failures in the design or construction process.

FMEA is not a substitute process for the engineering detail process. Instead, this approach is able to improve analytical techniques by applying knowledge and experience from past performance data to review the design progress of a product or process by assessing the risk of failure.

The steps taken in the FMEA analysis in this study are divided into four main steps. That is determining the severity of each failure finding. Determination of the severity index is obtained from the main trend of the results of pareto analysis. Then determining the physical detection degree of failure, then determining the repeat failure on each item finding and proceed with calculating the Risk Priority Number (RPN). The variables that will be used in the validation process do not cover all, but only the dominant trend results from pareto analysis. The purpose of FMEA is to find and reduce the risk of failure.

IV. ANALYSIS AND RESULTS

Analysis on 1st Research Problem

From the nine projects that were in progress of facade work and were the object of research, 949 findings of failure were obtained. The project which is the object of all research is the High Rise Building project and consists of various functions. Including 4 project office building projects, 4 apartments & Condominium projects, 1 project hospital.

The findings of the problems obtained from field observations are then grouped according to six parameters. The results of the problem grouping are then carried out by pareto trend analysis of the problem of facade failure during the construction period and the conclusions summarized in table 2 are obtained.

Table. 2 Façade Failure Trend Analysis

	<i>Frequency</i>	<i>Percentage (%)</i>	<i>Cummulative Percentage(%)</i>	<i>Rank</i>
Detail Engineering	345	36,35	36,35	1
Design	283	29,82	66,17	2
Supervision	140	14,75	80,93	3
Workmanship	101	10,64	91,57	4
Material	53	5,58	97,15	5
Fabrication	27	2,85	100	6

In table 2, it shows that from 949 findings from the problem of field observations, 66.17% is a failure caused by the process before construction. That is a failure due to detailed engineering errors of 36.35% and failure due to design errors of 29.82%. Whereas the next failure was caused by an error during the construction period, namely supervision failure of 14.75%.

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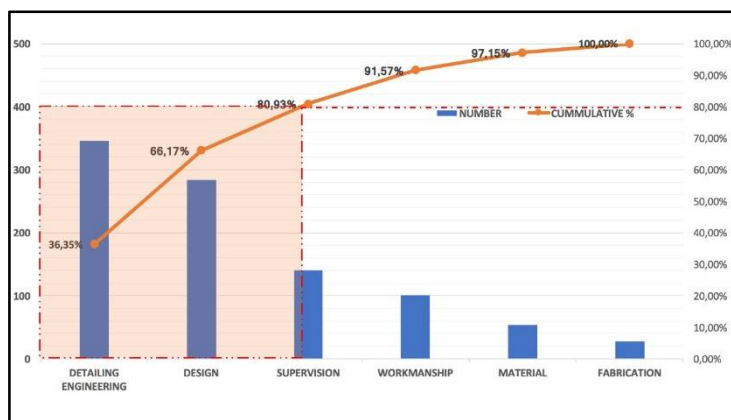
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In table 3 below it can be seen that the cumulative failure of 80% is the result of three parameter errors that occupy the highest ranking. That is detailed engineering, design and supervision.

Tabel 3. Failure Pareto Trend Graphic

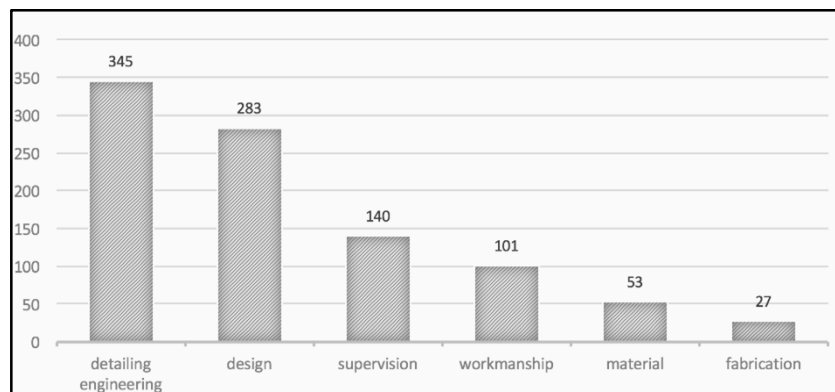


From graphic, can be seen the percentage of cumulative failure are dominated by detailed engineering failures and design failures. Followed by failure of supervision but not much.

Analysis of Contributors to Highest Failure

Every failures can be concluded that the dominant factor in the failure of facade during construction was dominated by a detailed engineering factor of 33.8%. Followed by design factors of 28.1% and caused by supervision of 16.5%. As for the graph of failure contributions from 949 failure items from pareto analysis obtained from 9 projects during the construction period are described by the following chart table 4 below:

Table 4. Failure Contribution Index



From the table 4 above we can see that the most contributor problem and performance facade that affects, it much caused by detailed engineering phase and design phase. And both of are included planning phase base on PMBOK.

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Failure Mode Effect Analysis (FMEA)

From the Pareto trend analysis it was found that contributors could be solved with detailed engineering, design errors and supervision errors. Each contributor analyzes FMEA to find out the highest items of each process carried out on these parameters.

In the detailed engineering stage there are glass finish specs and frames, glass resistance to condensation, splice joint transom detail, heater release spandrel area, perimeter joint sealant, metal sill flashing, top coping, block settings, connection details, flashing details, connection details and detail of Water Barrier.

Not all parameters are included in the FMEA analysis process. Because some variables do not become the scope of the study or are not relevant to the research conducted.

At the design stage there are several process items as follows: Design Guide, Thermal Break, Moisture Protection, Daylight & Aesthetic, Sound Reduction, Supporting CW, Safety Factor, maintainability.

When viewed from the parameters listed above, the reliability of the material and the façade of the supporting CW systems and movements are included in the FMEA analysis process. While other processes are not included with consideration of the process occurring before the construction process. As for supporting and reliability of glass, the failure can be known since the construction process. The reliability of material selection on movement must be a major consideration in the process of the detailed façade.

There is no opening check on the structural work contributing to the failure of the façade frame installation. The opening control process and façade frame dimensions are the key to the successful start of the window wall façade performance against leakage.

After determining the severity of each parameter which is a failure trend in the nine projects that are reviewed, the next is determining the physical detection rate. Kang Kok Hin (2005) in his research on façade service states that the physical degree of failure is a grouping index that describes the severity of failure. Here is a table of degrees of detection according to Kang Kok Hin.

Table 5 –Physical Detection Rate

Qualification	Condition
1	very easy to detect and prevention works very well
2	easily detected and preventive works well
3	Moderate and prevention methods sometimes work
4	It is difficult to detect and prevention methods are less effective
5	very difficult to detect and ineffective prevention methods

For the degree of frequency or occurrence manual calculation is carried out in each case that occurs. FMEA analysis is carried out as a whole, not done per project. The results of each of the definitions above, FMEA analysis is carried out with the results in table 6.

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Table 6 –Physical Detection Rate Analysis

	Design Phase			Detail Engineering																		Supervision		
	Broken Glass			Top Copping Facade			Sealpad + Shim Receiver			Sealant			Setting Block			ACP Detail Joint			Drainage System			Opening's Failure		
	Sev	Det	Num	Sev	Det	Num	Sev	Det	Num	Sev	Det	Num	Sev	Det	Num	Sev	Det	Num	Sev	Det	Num	Sev	Det	Num
A	-	-	0	4	4	23	4	5	8	4	3	15	3	4	18	4	3	23	4	2	5	3	4	16
B	-	-	0	4	4	43	5	4	7	3	4	13	4	4	10	5	4	9	3	3	12	3	2	13
C	3	3	9	5	4	15	3	3	4	4	3	22	-	-	0	5	3	22	3	3	14	4	5	18
D	-	-	4	4	4	19	2	3	8	2	3	24	3	4	12	4	4	22	3	3	15	-	-	0
E	2	4	6	5	4	17	2	2	9	2	2	16	4	4	8	5	3	20	3	4	15	3	3	17
F	-	-	0	4	4	22	4	3	9	3	4	18	4	4	8	4	4	21	3	3	13	4	4	14
G	-	-	0	4	4	28	2	4	12	2	5	21	-	-	0	4	3	31	3	4	12	-	-	0
H	-	-	0	4	4	21	4	4	12	4	4	16	4	4	12	5	3	31	4	4	12	-	-	0
I	5	5	12	4	4	11	5	4	5	4	3	21	3	4	10	4	4	19	4	3	12	4	2	15
Sum	10	12	31	38	36	199	31	32	74	28	31	166	25	28	78	40	31	198	30	29	110	21	20	93
Ave	3,333	4	3,444	4,222	4	22,11	3,444	3,556	8,222	3,111	3,444	18,44	3,571	4	8,667	4,444	3,444	22	3,333	3,222	12,22	3,5	3,333	10,33
FMEA	45,926			373,432			100,697			197,652			123,810			336,790			131,276			120,556		

Legend:

Sev = Severity index (severity)
Det = Physical Detection Rate (degree of detection)
Num = Number (Number of Events)

Sum = Amount
Ave = Average
FMEA = Failure Mode Effect Analysis
= (ave severity) X (ave detection) X (ave number)

Conclusion from the following FMEA validation table above, it was found that recurring errors in the façade work occurred in ACP connection work failures as well as top copping issue. This work are included the engineering detail process phase refer to PMBOK cycle project process.

V. CONCLUSION

From the results of the analysis of the trend problem or the potential problems that were found in the nine projects that were reviewed and observed, as well as the findings of the FMEA analysis, the potential failure of the façade in Jakarta has occurred since the phase before the construction phase getting started. Furthermore, in a review of this study, it was concluded that the failure of the façade performance item was a failure because the failures workson the top copping curtain walls and embankments on the window wall.

The conclusions of this study are:

1. The highest 80% of failure contributors to the façade work in Jakarta was caused by a detailed engineering error of 36.35%, followed by a design error of 29.82%, caused by a supervision error of 14.75%.
2. Repeated errors in the façade work occur in the detailed engineering process, namely an error in the top copping façade details, followed by details of the ACP cladding connection and followed by an error in the details of the sealant's work.
3. Referring to the life cycle of the project based on PMBOK, repeated errors and the highest failures contributors on facade are the phase of detailing engineering or planning phase.

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