


Chapter 10

Developing a Façade Risk Evaluation Framework (F-REF) Based on Failure Mode and Effects Analysis (FMEA)

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ABSTRACT

This chapter develops a Façade Risk Evaluation Framework (F-REF) grounded in Failure Mode and Effects Analysis (FMEA) for the systematic identification, comparison, and prioritization of façade risks across design, construction, and operation. The framework extends conventional FMEA through façade-specific severity, occurrence, and detection rubrics for unitized curtain walls and ventilated

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rainscreen systems; a façade-weighted priority index used alongside the traditional Risk Priority Number; dependency-based treatment of coupled failures; and full-matrix application across three façade scenarios with sensitivity testing under alternative weighting schemes. The chapter also positions F-REF against Fault Tree Analysis, Event Tree Analysis, Bow-Tie analysis, and qualitative checklist methods. Although further expert calibration is needed, the framework provides a more rigorous and actionable basis for façade risk screening, inspection planning, and lifecycle decision support.

1. INTRODUCTION

1.1 Importance of Risk Management in Façade Engineering

Façade systems have evolved from exterior building skins into complex engineering assemblies that influence structural behavior, environmental separation, energy performance, durability, and architectural expression. In contemporary buildings, especially high-rise and technically demanding projects, the façade acts as the primary interface between interior and exterior conditions and therefore plays a decisive role in weather protection, thermal regulation, occupant comfort, and operational performance (Kassem & Mitchell, 2015; Fernando et al., 2023). As integrated façade engineering has developed, designers have increasingly been required to balance structural, environmental, and architectural objectives within the same envelope system (Takeuchi et al., 2006; Kaneki et al., 2008; Inoue et al., 2003; Laufs & Verboon, 2013).

This increasing performance burden has been accompanied by greater technical complexity. Modern façades frequently incorporate unitized curtain walls, high-performance glazing, adaptive components, ventilated cavities, and advanced thermal interfaces. Attia et al. (2018) noted that contemporary façade systems are no longer judged only by enclosure function, but also by their contribution to comfort, energy efficiency, and responsive building performance. These developments create substantial opportunities, but they also increase the number of interfaces, tolerances, and failure pathways that must be controlled during design, fabrication, installation, and operation (Fernando et al., 2023).

Façade failures can have consequences that extend far beyond appearance. Water ingress, glazing breakage, detachment of cladding units, thermal bridging, sealant degradation, and concealed corrosion may affect safety, comfort, durability, energy use, and lifecycle cost. Straube and Burnett (2005) explained that enclosure failures are often difficult and expensive to diagnose because the visible symptoms may emerge only after hidden deterioration has advanced. Similarly, Santamaria-Fernandez et al.

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