Structural Evaluation of Four Frank Lloyd Wright Buildings

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Summary

This paper provides an overview of the investigation and analysis techniques that were used in the structural restoration of four significant buildings designed by Frank Lloyd Wright. The similarities and differences in evaluation and design aspects of the structural work for each building are presented. The lessons learned from each project's structural review, design, and repair procedures are also noted.

Keywords: historic preservation, non-destructive evaluation, laser scanning, Frank Lloyd Wright, finite element analysis, restoration, reinforcement.

1. Introduction

Frank Lloyd Wright (FLW) (1867-1959) was one of the most famous architects of the late 19th Century and early to mid 20th Century. His work helped to usher in the Modern Movement in Architecture throughout the United States.

Many of FLW's most recognizable designs made innovative use of structural materials. Either these materials were combined in architectural designs that were not commonly encountered previously or they made daring expressions of structural materials that were being pushed to their limits. In some cases these building elements were made of wood; in many cases they were made of steel and/ or reinforced concrete.

Because these buildings were often on the leading edge of structural and architectural technologies they have suffered from some premature deterioration of their structural systems. These systems may have had shortcomings of their original design, construction, detailing of associated architectural elements, poor alterations during the life of the building, severe deterioration environments, and/ or a lack of sympathetic maintenance.

This paper briefly reviews the structural investigations, analysis, and repair techniques that were used on four major buildings designed by FLW. They are:

Fallingwater, Bear Run, Pennsylvania (1937)

Solomon R. Guggenheim Museum, New York, New York (1959)

Johnson Wax Research Tower, Racine, Wisconsin (1950)

Wingspread, Racine, Wisconsin (1937)

2. Structural Conditions, Investigations, Analysis, and Repairs

2.1 The structural investigation, analysis, and repair designs included:

a. Close-up observation of field conditions.

b. Physical testing of material samples.

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c. Non-destructive evaluation of building materials.

d. Careful measurement of the existing building (for both dimensions and movement).

e. Completion of both basic and advanced structural analysis of the building elements (including finite element analysis (FEA) models).

f. Design of structural repairs that were minimally invasive. Some of these repairs combined both more common and more advanced structural materials.

3. Discussion and Conclusions

3.1 Common "Threads" of Structural Investigation of Buildings by FLW

There are a number of common "threads" to the structural investigation of buildings designed by FLW. Many of these are important aspects of the evaluation and repair of historic structures in general. Because many of these buildings represent prototypes or extreme examples of these structural systems, the careful investigation of the original design intents and the "as-built" details (including the condition of hidden structural members) is critical.

3.2 Significant Variations in the Structural Aspects of Buildings by FLW

Each building has a separate story to tell; there are several revealing variations in the structural systems of FLW buildings.

3.3 Lessons Learned from the Structural Investigation of Buildings by FLW

Working on the structural repairs and restoration of these four buildings there are several lessons that can be learned. The Structural Investigation of these buildings by FLW has revealed useful engineering judgments when strengthening, upgrading, and/ or restoring a building. These include the following:

a. Don't assume that your initial understanding of the building structural systems and/ or causes of deterioration are accurate or, indeed, represent the whole state of the structure.

b. Expect surprises and, in fact, look for hidden structural elements and details within structural members.

c. Don't trust the initial findings of destructive probes or non-destructive evaluation to be applicable to all areas of the building. A building can vary in unusual ways—in all three dimensions; symmetry should not be assumed. Review design and analysis assumptions made earlier in the investigation and revise these assumptions continually in the face of all new information. Be prepared for significant additional information to come to light at the start of demolition and during the actual construction efforts.

d. Look at all aspects of the building to evaluate structural performance.

e. Intensively look for construction that was built NOT in conformance with modern or contemporary standards.

f. Variation can occur even with buildings the same architect, same engineer, and/ or the same construction company.

g. Many of FLW's buildings were very much on the leading edge of structural design.

h. Decisions made by the original architects, engineers, and builders significantly impact the strength and durability of existing buildings. Always share with the owner and the entire design team your observations of these earlier decisions (e.g., the detail of a constructed joint between a gunite wall and a concrete floor slab).

i. When planning interventions on historic buildings always consider the sustainability and reversibility of the proposed change.