QUALITY CONTROL RECOMMENDATIONS FOR STRUCTURAL INTERVENTIONS ON HISTORIC PROPERTIES

By
Michele M. Holland

Thesis submitted to the Faculty of the Virginia Polytechnic Institute and State University in partial fulfillment of requirements for the degree of

MASTER OF SCIENCE
IN
CIVIL ENGINEERING

APPROVED:

__________________________
Dr. Richard Barker, Chairman

__________________________
Dr. Nadia Boschi

__________________________
Dr. Mehdi Setareh

October 30, 2001
Blacksburg, Virginia

Keywords: Historic Restoration, Historic Rehabilitation, Quality Control
Quality Control Recommendations for
Structural Interventions on Historic Properties

By

Michele M. Holland

Supervised by Richard M. Barker, PhD, Chairman
(Civil and Environmental Engineering)

(ABSTRACT)
This thesis presents recommendations for controlling quality in structural interventions on historic properties. Recognizing that establishing quality in the early stages of an intervention can set the standard of quality for an entire project, these recommendations are for the first phase of an intervention, the Pre-Construction Phase. To create these recommendations, first a literature review of past and present intervention methods is conducted. After breaking down the Pre-Construction Phase first into a series of steps, and then each step into a series of details, a standard of quality is established for each detail. The available methods for conducting each detail are then analyzed. Using the literature review and the established standards of quality, recommendations are made as to which method is most appropriate for a given project. These recommendations are applied to two case studies, the structural interventions of Boykin’s Tavern and Fallingwater. Finally, conclusions on the use of the proposed quality control recommendations are drawn, and suggestions are given for further work in this field.
ACKNOWLEDGEMENTS

My sincere thanks go to the members of my committee, Dr. Richard Barker, Dr. Nadia Boschi, and Dr. Mehdi Setareh, for being so patient with this document, which took much longer to finish than any of us ever imagined. Most especially, I thank my committee chair, Dr. Richard Barker, who came back from retirement to help me finish.

I would like to thank all my professors for having an open door whenever I had a question and for taking the time to teach all of us in ways that worked for us, no matter how unconventional. Furthermore, I thank my fellow graduate students, who became friends as well as classmates. I could not have succeeded without their support and encouragement.

I thank my parents for their continued support of my endeavors, and their commitment to doing whatever it takes to help me succeed. Finally I thank my brother, whose unshakable faith in me has given me faith in myself when I’ve needed it most.
DISCLAIMER

The information presented herein is based on recognized engineering principles and is for general information only. While it is believed to be accurate, this information should not be applied to any specific application without competent professional examination and verification by a licensed professional engineer. Anyone making use of this information assumes all liability arising from such use.
# TABLE OF CONTENTS

Abstract iii  
Acknowledgements iv  
Disclaimer v  
Table of Contents vi  
List of Tables vii  
List of Figures viii  
Chapter 1 – Introduction 1  
Chapter 2 – Literature Review 4  
  APPROACH 4  
  METHODOLOGY 8  
  Initial Project Objectives 8  
  Data Collection 9  
  Final Project Objectives 20  
  Project Budget 20  
  Structural Intervention 21  
Chapter 3 – Standards of Quality 23  
  APPROACH 23  
  METHODOLOGY 24  
  Initial Project Objectives 25  
  Data Collection 26  
  Final Project Objectives 30  
  Project Budget 30  
  Structural Intervention 30  
Chapter 4 – Quality Control Recommendations 32  
  APPROACH 32  
  METHODOLOGY 34  
  Initial Project Objectives 35  
  Data Collection 35  
  Final Project Objectives 39  
  Project Budget 39  
  Structural Intervention 41  
Chapter 5 – Case Study: Boykin’s Tavern 43  
  THE INTERVENTION 43  
  Initial Project Objectives 43  
  Data Collection 44  
  Final Project Objectives 47  
  Project Budget 47  
  Structural Intervention 47  
  LESSONS LEARNED 50  
Chapter 6 – Case Study: Fallingwater 52  
  THE INTERVENTION 52  
  Initial Project Objectives 52  
  Data Collection 52  
  Final Project Objectives 55  
  Project Budget 56  
  Structural Intervention 56
## List of Tables

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Table 1</td>
<td>Summary of the Pre-Construction phase of a structural intervention</td>
<td>2</td>
</tr>
<tr>
<td>Table 2</td>
<td>Synopsis of Attar’s elements of Authenticity</td>
<td>7</td>
</tr>
<tr>
<td>Table 3</td>
<td>Synopsis of Attar’s four categories of structural intervention</td>
<td>8</td>
</tr>
<tr>
<td>Table 4</td>
<td>Summary of the Secretary of the Interior’s intervention philosophies</td>
<td>9</td>
</tr>
<tr>
<td>Table 5</td>
<td>Summary of the indicators of authenticity from the Declaration of San Antonio</td>
<td>10</td>
</tr>
<tr>
<td>Table 6</td>
<td>Synthesis of Rabun’s and Silman’s tables on testing methods</td>
<td>17</td>
</tr>
<tr>
<td>Table 7</td>
<td>Summary of Kelley’s elements of structural stability</td>
<td>22</td>
</tr>
<tr>
<td>Table 8</td>
<td>National Register of Historic Places’ Criteria for Evaluation</td>
<td>27</td>
</tr>
<tr>
<td>Table 9</td>
<td>Summary of Quality Control Recommendations</td>
<td>42</td>
</tr>
</tbody>
</table>
# LIST OF FIGURES

<table>
<thead>
<tr>
<th>Figure</th>
<th>Description</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Figure 1</td>
<td>Relationship of hierarchy and quality</td>
<td>25</td>
</tr>
<tr>
<td>Figure 2</td>
<td>Boykin’s Tavern</td>
<td>43</td>
</tr>
<tr>
<td>Figure 3</td>
<td>Side view of Boykin’s Tavern</td>
<td>46</td>
</tr>
<tr>
<td>Figure 4</td>
<td>Channels sistered with joists</td>
<td>48</td>
</tr>
<tr>
<td>Figure 5</td>
<td>Chimneys of Boykin’s Tavern</td>
<td>49</td>
</tr>
<tr>
<td>Figure 6</td>
<td>New addition to Boykin’s Tavern</td>
<td>49</td>
</tr>
<tr>
<td>Figure 7</td>
<td>Fallingwater</td>
<td>52</td>
</tr>
<tr>
<td>Figure 8</td>
<td>SAP90 Model of Fallingwater’s Master Terrace</td>
<td>54</td>
</tr>
<tr>
<td>Figure 9</td>
<td>Deflection over time of Fallingwater’s Master Terrace</td>
<td>55</td>
</tr>
</tbody>
</table>
CHAPTER 1
INTRODUCTION

A structure that is at least fifty years old and meets the established and internationally accepted criteria of historical significance is considered historic. Aging, environmental conditions, and poor maintenance all contribute to the degradation of historic properties. Severe damage can lead to the need for a structural intervention – the strategic strengthening of a building to make it structurally stable. By the nature of the work involved, structural interventions may significantly affect the authenticity and integrity of historical structures. These added constraints of preserving historic authenticity and integrity introduce new standards of quality for a structural intervention on a historic building. A quality structural intervention on a historic building is one that completes all the necessary structural work with the least invasive procedures and alterations to the historic fabric.

The difficulty with attaining this quality work is knowing first how to quantify it throughout the intervention, and second how to control it. Quality can be quantified by discretizing quality into a number of standards, with each standard being associated with some detail of the intervention. For the purpose of discretizing quality, the intervention can be broken down into four phases: Pre-Construction, Construction, Commissioning, and Operation/Maintenance.

By placing a series of checks and balances on these standards within each phase of the intervention, quality can be controlled. Though quality control must be carried out through all phases of the intervention, the Pre-Construction phase, broken down in Table 1, is the most crucial. Focusing on quality control in the Pre-Construction Phase will build quality into the intervention design, thereby assuring a desired standard of work. Furthermore, quality control in the Pre-Construction Phase assures that the intent of the intervention will be reflected throughout the work.

The objective of this thesis is to establish a set of criteria by which to measure quality and a set of methods for controlling this quality in the Pre-Construction phase of structural
interventions on historic properties. Using this information allows structural intervention plans to be developed more easily and with less confusion. Consequently, the remainder of the intervention can be performed more easily as well, as the Pre-Construction phase sets the pace for the rest of the project. It should be noted that structural interventions involve many more details than are listed here, such as Mechanical/Electrical/Plumbing design, Air Quality assurance, etc. This thesis focuses solely on those details that directly impact the structural aspects of the intervention.

Table 1. Summary of the Pre-Construction Phase of a structural intervention

<table>
<thead>
<tr>
<th>PHASE</th>
<th>STEPS</th>
<th>DETAILS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pre-Construction</td>
<td>Initial Project Objectives</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Data Collection</td>
<td>Statement of Historic Significance</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compliance with Building Codes</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Compliance with Section 106 of NHPA</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Structural Assessment</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Diagnosis of Building Performance</td>
</tr>
<tr>
<td>Final Project Objectives</td>
<td></td>
<td>Anamnesis</td>
</tr>
<tr>
<td>Project Budget</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Structural Intervention</td>
<td>Structure Intervention Plan</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>Structural Intervention Design</td>
</tr>
</tbody>
</table>

To accomplish this objective, this thesis is broken down into a series of chapters that provide the background to create the recommendations, present the recommendations, test the recommendations, and finally evaluate the use of the recommendations.

The second chapter of this thesis is a literature review of structural interventions on historic buildings, that follows the framework of Table 1 and focuses on how structural interventions have been handled in the past and how they are handled currently. Specifically, the approach to, and methodology of, past and current interventions are presented, with an emphasis on how quality has been improved through the use of current approaches and methodology.
In the third chapter, quality is defined and quantified in terms of what the result of the intervention should be. First, quality on a global level is addressed by analyzing each aspect of the intervention approach, such as pre-qualifying professionals and laborers. Quality is then quantified on a local level by defining it for each individual detail in the Pre-Construction phase, such as structural assessment. By defining the criteria for quality on this level, quality can then be measured against the established standard.

The fourth chapter creates a set of recommendations for controlling quality. These recommendations are drawn from the literature review in chapter 2 and the criteria for measuring quality in chapter 3. The recommendations are structured in the same manner as the criteria for quality, focusing first on the global and then on the local level.

As a means of demonstrating these standards of quality and recommendations for quality control, two case studies are presented in the fifth and sixth chapters. The structural interventions on Boykin’s Tavern in Isle of Wight, Virginia and Fallingwater in Bear Run, Pennsylvania are analyzed. Specifically, each of these analyses includes a detailed description of the structure, a summary and analysis of the intervention, and an assessment of the intervention using the recommendations created in the fourth chapter.

The final chapter summarizes the information presented throughout the thesis. Further, it provides conclusions on the proposed quality control recommendations, and makes suggestions for further developments in this field.
CHAPTER 2
LITERATURE REVIEW

APPROACH

Structural interventions on historic structures have evolved through the years, in both approach and methodology. By studying past and current practices, a basis for developing quality control standards for structural interventions can be formed. The following paragraphs provide a literature review of the evolving role of the engineer in structural interventions, and give an overview of the engineer’s impact on quality on a global level.

THE ROLE OF THE STRUCTURAL ENGINEER

First and foremost in the evolution of structural interventions on historic structures, the role of the engineer has changed significantly over the years. This has led to an improved level of quality in these interventions. In a series of articles in the APT (Association for Preservation Technology) Bulletin in the early 1990’s, structural engineers Stephen J. Kelley, Michael Lynch, and Ghassan Attar discussed the past, current, and future roles of the structural engineer in the field of historic preservation.

In “Forum on Conservation Engineering” (Kelley and Lynch, 1991), Kelley and Lynch describe the emergence of conservation engineering as a recognized engineering discipline. From a roundtable discussion at a conference of preservation professionals in 1990, the term “conservation engineer” (sometimes referred to as “preservation engineer”) was first defined as:

Conservation engineer: a practicing engineer who through knowledge, training, experience and skill provides technical services in conformance with established conservation principles.

The article went on to describe “established conservation principles” as those presented in the Secretary of the Interior’s Standards for the Treatment of Historic Properties, the Charter of Venice, and other accepted publications of current preservation standards. Such publications include those that define UNESCO (United Nations Educational, Scientific, and Cultural Organization) conventions for conservations, and ICOMOS
(International Council on Monuments and Sites) regulations and guidelines, such as the Declaration of Amsterdam.

This roundtable discussion also brought forth the concern over the then limited role of the structural engineer in the intervention process. The article indicated that the participants believed that involving the engineer in the beginning of the intervention would allow for the most effective use of the engineer’s skills.

Finally, the article acknowledged that because there was no defined field of conservation engineering, the NPS (National Park Service) had not yet established minimum criteria for certification of professional engineers practicing in the field of historic preservation. This meant an engineer could not serve as prime consultant on federal-grant assisted contracts, which was viewed as a limiting factor in the engineer’s role in the intervention process.

By publishing the first formal definition of a conservation engineer, Kelley and Lynch helped define what is now a small but growing field of specialists in the varying disciplines of engineering, most notably structures. Furthermore, their discussion paved the way for courses in conservation engineering at many major technical colleges and universities, and the establishment of conservation engineering as a course of study at some of these institutions. This formal training and education has helped lead to the inclusion of the structural engineer as a member of the intervention design team on many major projects, though most smaller projects still do not follow this trend.

Unfortunately, the Secretary of the Interior’s Historic Preservation Professional Qualification Standards of 1983 are still in effect, so no official definition of a conservation engineer yet exists. The NPS established these standards to “ensure that a consistent level of expertise would be applied nationally to the identification, evaluation, documentation, registration, treatment, and interpretation of historic and archeological resources”. At that time, only five disciplines were evaluated, namely: Architecture, Architectural History, Prehistoric Archeology, Historic Archeology, and History.
A proposed amendment to this document was made in 1997, and while it has not yet been adopted, NPS professionals say it is a reflection of the Park Service’s current thinking on the issues of professional qualifications (NPS, 1997). These Standards identify the twelve disciplines “key to the responsible practice of historic preservation” as: Archeology (Prehistoric and Historic), Architectural History, Conservation, Cultural Anthropology, Curation, Engineering, Folklore, Historic Architecture, Historic Landscape Architecture, Historic Preservation Planning, and History. Each Standard defines minimum qualification requirements for academic degrees or training, professional experience, and products and activities that demonstrate proficiency in historic preservation. Furthermore, each Standard is introduced by a synopsis of the discipline’s role in historic preservation. While the Standards are primarily advisory in nature, the preface of the Standards notes, “...States, local governments, Federal agencies, and the private sector often require that proposals from historic preservation contractors or work submitted by them meet these same professional practice Standards”. Adoption of this document would expand the number of professionals qualified to manage preservation projects to include engineers, as well as others.

Kelley and Lynch’s article provided the first formal definition of a conservation engineer. Ghassan Attar’s article, “Authenticity vs. Stability: The Conservation Engineer’s Dilemma” (Attar, 1991) further defines the need for a specially trained structural engineer to perform a structural intervention, and provided a more specific definition of a “qualified” conservation engineer.

“A qualified conservation engineer”, Attar writes,

“must have the training, experience, and sensitivity to apply established conservation principles and rigorous engineering conventions to the determination of appropriate levels of intervention”. (Attar, 1991)

He further recommends “the following skills...as a minimum”

- Knowledge of period and contemporary building materials
- Knowledge of period and contemporary building systems
- Knowledge of traditional methods of engineering analysis
• Knowledge of techniques of physical investigation, especially non-destructive testing methods
• Ability to detect and interpret building problems
• Ability, and willingness, to take calculated risks, and
• Ability to work with a diverse multi-disciplinary team of professionals including architects, other engineers, historians, archeologists, public administrators, exhibit designers, the public, and the client.

In addition to Attar’s contribution of a definition of a qualified conservation engineer, his article presents two key concepts that clearly establish the separate nature of a structural intervention from a conventional historic intervention. The first, summarized in Table 2, is the concept of structural authenticity. The second is the relationship between the categories of a structural intervention and of a historic intervention.

Table 2. Synopsis of Attar’s elements of Authenticity (Attar, 1991).

| AUTHENTIC MATERIALS | Original materials used in construction establish authenticity because they are “the basic elements of the historic property”. |
| AUTHENTIC CONSTRUCTION SYSTEMS | A construction system establishes authenticity by indicating which parts of a structure are original, and which are additions. The construction system may also establish the period of the structure’s construction, based on when systems were most prevalently used. |
| AUTHENTIC CONSTRUCTION METHODS | Like construction systems, construction methods can establish authenticity by dating the period of the structure’s construction, based on when methods were most prevalently used. |

Historic preservation has long had four well-defined categories of intervention, namely preservation, rehabilitation, restoration, and reconstruction. In this article, Attar defines four related categories for structural intervention, specifically, stabilization, consolidation, rehabilitation, and reconstruction (See Table 3.). Through these detailed definitions of authenticity and stability, Attar is able to introduce a method of measuring the affect of a structural intervention on a property’s historic authenticity.
Table 3. Synopsis of Attar’s four categories of structural intervention (Attar, 1991).

<table>
<thead>
<tr>
<th><strong>STABILIZATION</strong></th>
<th>Preserving the existing historic property in its present condition by slowing down the effects of aging and arresting abnormal deterioration.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>CONSOLIDATION</strong></td>
<td>Improving the condition of existing materials and systems. This usually involves the introduction of new materials or construction methods.</td>
</tr>
<tr>
<td><strong>RESTORATION</strong></td>
<td>Recovering the form, function, detailing and strength of a specific period in the property’s history. Includes removal of later additions and/or replacement of missing original elements.</td>
</tr>
<tr>
<td><strong>RECONSTRUCTION</strong></td>
<td>Reproduction in whole or in part of a destroyed or poorly preserved historic property. A period reconstruction is an accurate replica of a property or element as it appeared at a specific period of time.</td>
</tr>
</tbody>
</table>

**METHODOLOGY**

A literature review of the steps and details of the Pre-Construction phase summarized in Table 1 is presented in the paragraphs that follow.

**INITIAL PROJECT OBJECTIVES**

Establishing initial project objectives involves a number of variables, the majority of which are project dependent. In general, these objectives should provide a clear vision of the future use of the structure. The first objective that must be established is the intervention philosophy that is most appropriate for the structure and the owner’s needs, as this will guide the remainder of the steps of the Pre-Construction phase. First established in the Athens Charter of 1931 (ICOMOS, 1931), and further expanded in the Venice Charter of 1964 (ICOMOS, 1964), there are four major philosophies in historic interventions. The most recent and accepted versions of these philosophies can be found in The Secretary of the Interior’s Standards for the Treatment of Historic Properties of 1995 (Code, 1995). Specifically, this document includes a detailed description of each of the four accepted philosophies of historic interventions: preservation, rehabilitation, restoration, and reconstruction (see Table 4).
Table 4. Summary of the Secretary of the Interior’s intervention philosophies (Code, 1995).

<table>
<thead>
<tr>
<th><strong>PRESERVATION</strong></th>
<th>The act or process of applying measures necessary to sustain the existing form, integrity, and materials of an historic property.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>REHABILITATION</strong></td>
<td>The act or process of making possible an efficient compatible use for a property through repair, alterations, and additions while preserving those portions or features which convey its historical, cultural, or architectural values.</td>
</tr>
<tr>
<td><strong>RESTORATION</strong></td>
<td>The act or process of accurately depicting the form, features, and character of a property as it appeared at a particular period of time by means of the removal of features from other periods in its history and reconstruction of missing features from the restoration period. The limited and sensitive upgrading of mechanical, electrical, and plumbing systems and other code-required work to make properties functional is appropriate within a restoration project.</td>
</tr>
<tr>
<td><strong>RECONSTRUCTION</strong></td>
<td>The act or process of depicting, by means of new construction, the form, features, and detailing of a non-surviving site, landscape, building, structure, or object for the purpose of replicating its appearance at a specific period of time and in its historic location.</td>
</tr>
</tbody>
</table>

**DATA COLLECTION**

**Statement of Historic Significance**

The Statement of Historic Significance is the first part of the Data Collection step, and is comprised of historic context, criteria of historic significance, and authenticity.

The “National Register Bulletin: Guidelines for Evaluating and Nominating Properties that have Achieved Historic Significance within the Past Fifty Years” (National Register, 1998) provides a definition of historic context. “Historic context refers to all of those historic circumstances and factors from which the property emerged.”

“The National Register Criteria for Evaluation” (Dept. of Interior, 1998) provide criteria to determine if a structure technically qualifies as a historically significant structure. Additionally, the NPS has an on-line guide with tips on how to recognize potentially historic significant elements of a structure (www.cr.nps.gov).
The Nara Document on Authenticity of 1994 (UNESCO, 1994) outlines the importance of authenticity, stating in Article 10, “Authenticity...appears as the essential qualifying factor concerning values.” Built on the Nara Document, the 1994 Declaration of San Antonio (ICOMOS, 1996) presents five indicators of authenticity (see Table 5) to aid in establishing authenticity of a historic property.

Table 5. Summary of the indicators of authenticity from the Declaration of San Antonio (ICOMOS, 1996).

<table>
<thead>
<tr>
<th>REFLECTION OF THE TRUE VALUE</th>
<th>Whether the resource remains in the condition of its creation and reflects all its significant history.</th>
</tr>
</thead>
<tbody>
<tr>
<td>INTEGRITY</td>
<td>Whether the site is fragmented; how much is missing, and what are the recent additions.</td>
</tr>
<tr>
<td>CONTEXT</td>
<td>Whether the context and/or the environment correspond to the original or other periods of significance and whether they enhance or diminish the significance.</td>
</tr>
<tr>
<td>IDENTITY</td>
<td>Whether the local population identify themselves with the site, and whose identity the site reflects.</td>
</tr>
<tr>
<td>USE AND FUNCTION</td>
<td>The traditional patterns of use that have characterized the site.</td>
</tr>
</tbody>
</table>

Utilizing the definitions of historic content, criteria of historic significance, and authenticity, the Statement of Historic Significance can be created. In order to utilize the Statement throughout the project, each of the elements must be documented. Documentation of the historic context, criteria of historic significance, and authenticity of a property can be found in a variety of sources. The National Register offers sample nomination forms, which draw documentation from such sources as: maps, photographs, letters, diaries, deeds, biographies, local history collections, and newspapers (National Register, 1998).

**Compliance with Building Codes**

Though all construction must comply with the applicable model code requirements, historic properties undergoing an intervention are subject to three requirements in particular: occupancy criteria, accessibility requirements, and disaster mitigation codes. (Energy efficiency is another requirement that historic properties must address during an intervention, but it is beyond the scope of this work.) Historic properties are subject to less restrictive regulations, but still must comply with these requirements, as laid out
in the local building codes. In the past, each of the most notable model codes (BOCA, SBC, UBC) dealt with historic properties within the subtext of the Existing Buildings section. But the applicability of these codes was unclear. For instance, in the 1996 BOCA (Building Official and Code Administrators) code (BOCA, 1996), historic properties were discussed in Section 3406.0 Historic Structures, which stated,

“The provisions of this code relating to the construction, repair, alteration, addition, restoration and movement of structures shall not be mandatory for existing buildings and structures identified and classified by the federal, state, or local government authority as historic buildings where such buildings are judged by the code official to be safe and in the interest of public health, safety and welfare regarding any proposed construction, alteration, repair, addition, and relocation.”

Under these terms, buildings were then potentially (depending on the determination of the building official) subject to the conditions of Section 3404.0 Alterations. Specifically, Section 3404.2 Requirements stated, in part:

An alteration to any structure shall conform to the code requirements for a new structure and shall not result in an increase in hazard to the occupants....

The SBC (Standard Building Code) (SBCCI, 1997) and the UBC (Uniform Building Code) (ICBO, 1997a) were similarly vague by leaving open such questions as: When is a change a “repair” and when is it an “alteration”? What constitutes “an increase in hazard to the occupants”? Clearly, much of the applicability of these codes to a historic building was left in the hands of the local building official.

In 2000, these model codes merged to form the IBC (International Building Code) (ICC, 2000). Yet the vagueness remains. Section 3406 Historic Buildings states,

The provisions of this code relating to the construction, repair, alteration, addition, restoration and movement of structures, and change of occupancy shall not be mandatory for historic buildings where such buildings are judged by the building official to not constitute a distinct life safety hazard.

Previously, the UBC was supplemented by a publication entitled The Uniform Code for Building Conservation, (UCBC) (ICBO, 1997b), which was intended to be adopted as part of the local building code, or used as a guideline. Today this publication is called Guidelines for the Rehabilitation of Existing Buildings, (ICBO, 2001), and serves in a
similar capacity. Additionally, there is the “Nationally Applicable Recommended Rehabilitation Provisions” (NAARP) (HUD, 1998).

Once the historic property is determined by the code official to be subject to the applicable provisions of the local building code, the aforementioned requirements of occupancy criteria, accessibility, and disaster mitigation must be satisfied.

*Occupancy Criteria*

Occupancy criteria must be established to develop a structural design of any kind, including that of a historic intervention. Occupancy limits arose from a number of tragedies due to overloading of a structure, or lack of sufficient fire egress. Occupancy limits are determined by local building codes. Building codes in the past varied widely between cities, and often did not adequately address all necessary issues. Today, Change of Occupancy is one of the criteria listed in the Existing Structures of the IBC, and is largely left to the discretion of the building code official. Occupancy criteria must be verified by a Certificate of Occupancy, issued by the building code official (ICC, 2000).

*Accessibility Requirements*

The accessibility requirements of a building are determined by the ADA (Americans with Disabilities Act of 1990). This document and its subsequent revisions provide specific requirements with which all new structures must comply. Section 3408 of the IBC applies to “Accessibility for Existing Buildings”, and its scope is defined in 3408.1, which states

> The provisions of Sections 3408.2 through 3408.8.5 apply to maintenance, change of occupancy, additions and alterations to existing buildings, including those identified as historic buildings.

Again, the local building code official must determine what constitutes a “change of occupancy”, “addition”, “alteration”, and “maintenance”.
The Secretary of the Interior’s Standards for the Treatment of Historic Properties (Code, 1995) gives some guidance on the acceptable methods of introducing ADA requirements into historic properties. Additionally, the NPS Preservation Brief 32 (NPS, 1993) provides more specific guidelines for this kind of work, suggesting a three-step approach:

1. Review the historical significance of the property and identify character-defining features
2. Assess the property's existing and required level of accessibility
3. Evaluate accessibility options within a preservation context

Disaster Mitigation Requirements

The heading of “disaster mitigation” refers to potential faults or failures due to flooding, earthquakes, or other natural disasters. A general statement of the relationship between disaster mitigation and historic properties is made in FEMA’s “National Preservation Model State Programmatic Agreement” (FEMA, 1999), which seeks “to further simplify and expedite the Section 106 process of the National Historic Preservation Act (NHPA), incorporate FEMA program changes into the agreement, and strengthen relationships and cooperation between FEMA, the Advisory Council for Historic Preservation, the State Historic Preservation Offices (SHPO), and State Emergency Management Agencies (SEMA) before a disaster occurs.”

IBC 2000 provides code regulations for flood, seismic, and wind loading, including some sections for existing buildings. Additionally, the Federal Emergency Management Agency (FEMA) has produced a number of publications dealing with these issues. They provide guidance on what is required, what is recommended, and suggested methods of carrying out the recommendations.

“Engineering Principles and Practices for Retrofitting Flood Prone Residential Buildings” (FEMA, 1995) is an extensive text (over 400 pages) on methods of flood mitigation techniques for existing buildings. “After the Flood: Rehabilitating Historic Resources” (Georgia Dept. of Resources, 1995) is a practical guide for rehabilitating a historic property damaged by flooding.
The 1998 “NEHRP Guidelines for the Seismic Rehabilitation of Existing Buildings (FEMA 273)” (FEMA, 1998) was published with a commentary (“NEHRP Commentary on NEHRP Guidelines for the Seismic Rehabilitation of Existing Buildings (FEMA 274)” by the National Earthquake Hazards Reduction Program (NEHRP) in conjunction with FEMA (FEMA, 1998). These Guidelines include the first performance-based design concepts for seismic retrofitting, and can be applied to all existing structures in all areas of the country. Additionally, a former appendix of the UCBC has been broken out into a separate publication, “Guidelines for Seismic Retrofit of Existing Buildings” (ICBO, 2000). This publication deals with existing buildings in general, and specifically with the seismic retrofit of historic buildings. Another publication of some interest in this area is “Temporary Shoring & Stabilization of Earthquake Damaged Historic Buildings” (Harthorn, 1998), which provides some additional methods for seismically retrofitting historic buildings.

Compliance with Section 106 of NHPA

Section 106 of the National Historic Preservation Act (NHPA) of 1966 requires

“…Federal agencies to take into account the effect of their undertakings on properties included in or eligible for inclusion in the National Register of Historic Places and to afford the Council a reasonable opportunity to comment on such undertakings.”

(The full text of the NHPA and subsequent revisions are available through the National Advisory Council on Historic Preservation as 36 CFR Part 800 (NHPA, 2001).) This protects historic properties on, or potentially on, the National Register from inappropriate and potentially damaging interventions by requiring a review of the intervention plan by the National Advisory Council on Historic Preservation (NACHP), a group with expertise in acceptable methods of historic interventions.

Structural assessment

The structural assessment of a building entails the analysis of a building’s structural systems and materials to determine the structural integrity of the building. Stanley J.
Rabun’s Structural Analysis of Historic Buildings (Rabun, 2000) provides a systematic summary of the two phases of structural assessment for an existing building (see Tables 9 and 10, in chapter 4). These summaries include all the major steps of a structural intervention, namely:

1. Study of available documentation
2. Identification of construction, load paths
3. Inspection process, involving visual identification of defects
4. Analysis of failure considerations
5. Estimation of actual loads on the building
6. Determination if structure is adequate as it exists, or if alterations are necessary
7. Determination of the need for a more detailed assessment

Many details are included within each of these steps. Rabun provides adequate background information for many details, but a further literature review is prudent for two of the major details – materials testing and mathematical modeling. These aspects of structural assessment have evolved - and continue to evolve - to an astonishing level, and provide increasingly accurate data on the condition of the materials and structural systems in existing historic properties.

*Materials Testing*

Materials testing consists of destructive and non-destructive (NDT) methods. Though NDT is less damaging to the historic fabric, destructive testing methods may be appropriate in some cases, due to budget constraints or limited impact of the testing on the historical integrity of the property. The American Society for Testing Materials (ASTM) provides standards for the testing of various materials, both in-situ and with removed samples (ASTM, 1989).

Robert Silman’s article, “Applications of Non-Destructive Evaluation Techniques in Historic Buildings” (Silman, 1996), presents the evolution of NDT (non-destructive testing), along with an analysis of the various methods, including relative costs. This article explains that testing of materials in historic properties was once a necessarily invasive and destructive process. The testing involved the cutting away and removal of
some portions of walls and floors to determine the state of the materials in-situ. Thirty years ago, NDT consisted of X-Ray technology, which involved expensive, cumbersome equipment, long exposure times, and large emissions of radiation. Today’s technology includes such methods as: impulse radar, impact echo, ultrasonic pulse velocity, spectral analysis of surface waves, electromagnetic detection, infrared thermography, and fiber optics. Though many of these methods are expensive and require complex equipment, they produce precise results, and can be used to save money in the design by providing definitive information on the capacity of the existing structural system.

In Rabun’s *Structural Analysis of Historic Buildings*, the author references Wilson’s *Building Materials Evaluation Handbook* (Wilson, 1984) as providing a summary of various testing methods, their application, results, and limitations. Table 6 is a synthesis of this table and Silman’s table, “Applicability of Non-Destructive Testing”.

<table>
<thead>
<tr>
<th><strong>TEST SPECIMEN</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Results</strong></td>
<td>Stress-strain data, yield point, ultimate strength, tension or compression</td>
</tr>
<tr>
<td><strong>Limitations</strong></td>
<td>Required sample too large to take out of existing member without leaving member in distress</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>X RAY, GAMMA RAY</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Results</strong></td>
<td>Detects both internal and external flaws. Voids or low-density areas show up on film. Can detect flaws or stress fatigue in weld as well as metal.</td>
</tr>
<tr>
<td><strong>Limitations</strong></td>
<td>Expensive. Cumbersome equipment. Large emissions of radiation.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>EDDY CURRENT</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Results</strong></td>
<td>Detects discontinuities, cracks, seams, and variations in alloys.</td>
</tr>
<tr>
<td><strong>Limitations</strong></td>
<td>Qualitative comparisons only</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>ELECTRO-MAGNETIC DEVICES</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Results</strong></td>
<td>Detects cracks, seams, laps, voids, porosity, and inclusions. Senses flaws down to ¼” below surface. Has been used to find: reinforcing bars, iron and steel beams and columns, masonry ties, pipes, and leaders (cast iron)</td>
</tr>
<tr>
<td><strong>Limitations</strong></td>
<td>Does not require trained operator; (purchase costs ~ $550)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>ACOUSTICAL METHODS</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Results</strong></td>
<td>Detect surface and subsurface defects. Various methods measure thicknesses from 14” to 24”. Detects delaminations, voids, cavities, and other discontinuities.</td>
</tr>
<tr>
<td><strong>Limitations</strong></td>
<td>Transmitter and receiver must be on opposite side of test specimen. Pulse-echo can be used if only one side accessible, but results not as accurate. Requires trained, experienced operator. Expensive (Daily rental ~ $6,000)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>INFRARED THERMOGRAPHY</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Results</strong></td>
<td>Can locate sources of moisture in walls. Can locate internal drains, leaks in recessed gutters, concealed flues, position of wood posts and braces in exterior walls.</td>
</tr>
<tr>
<td><strong>Limitations</strong></td>
<td>Equipment must be cooled in liquid nitrogen tank. Requires thermal differential between inside and outside of building. Requires a trained, experienced operator. Expensive (Daily rental ~ $3,500)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>IMPULSE RADAR</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Results</strong></td>
<td>Detects defects in construction assembly; position, size, of reinforcing bars; pour joints; location of beams, columns, etc.</td>
</tr>
<tr>
<td><strong>Limitations</strong></td>
<td>Requires an experienced, trained operator and an expert to interpret results. (Daily rental and interpretation of results ~ $6,500)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>LIQUID PENETRANT (CONTAINING DYE)</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Results</strong></td>
<td>Penetrates defects, dye shows through over time</td>
</tr>
<tr>
<td><strong>Limitations</strong></td>
<td>Time consuming examination of surface for marked defects</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>VISUAL-OPTICAL</strong></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Results</strong></td>
<td>Detects surface defects, cracks, corrosion; useful in limited access areas, such as cavity walls</td>
</tr>
<tr>
<td><strong>Limitations</strong></td>
<td>Limited use, but inexpensive (~ $600 for daily rental, or $6,000 to purchase).</td>
</tr>
</tbody>
</table>
Mathematical Modeling

In the past, determining the load capabilities of an existing structure was very difficult. As-built drawings of historic structures can be difficult to locate, are rarely complete, and often do not reflect all the additions or modifications of a structure. Hand calculations had to be utilized to analyze a structural system, and errors in construction were difficult to account for in these calculations. The technological capabilities for analyzing an existing structure have continually improved to provide increasingly accurate results. Commercially available finite element computer programs allow for accurate modeling of existing conditions and loadings, and provide output that indicate member stresses, predicted deflections, and drift of the structure. What these programs cannot provide is information on historic construction methods and/or materials. This information is available in Rabun’s *Structural Analysis of Historic Buildings* (Rabun, 2000). This comprehensive text provides design loads for roofs and floors, material strengths, and methods for determining the strength of existing structural systems. This data, combined with new methods of analysis, makes the determination of the capacity of an existing structure more manageable than in the past.

Diagnosis of Building Performance

A diagnosis of building performance involves the analysis and evaluation of a building’s structural, energy, and airflow systems. These systems indicate the “health” of the building, reveal information about the “constant degradation” of the property, and indicate any needs for upgrading to meet code requirements. All of these are important aspects in any intervention, though obviously the analysis of the structural system is key in the structural intervention. The physical investigation of the property in the structural assessment indicates if hazardous materials are present in the structural system. The rate of decay of the structural system is dependent upon the materials, which are analyzed in the structural assessment. The efficiency of the structural system is best determined through the structural analysis.
Anamnesis

In medical context, an anamnesis is the complete case history of a patient. In structural context, an anamnesis is the complete history of a building and all its systems. The most complete and accurate anamnesis of a historic structure is presented in a Historic Structure Report (HSR).

The HSR is best explained by (ASTM)’s “Guide for Preparation and Use of Historic Structure Reports” (ASTM, 1990). This document defines an HSR as

a document prepared for a building, structure, or group of buildings and structures of recognized significance to record and analyze the property’s initial construction and subsequent alterations through historical, physical and pictorial evidence; document the performance and condition of the building’s architectural materials and overall structural stability; identify an appropriate course of treatment; and document alterations made through the treatment.

Additionally, this document does, as its title suggests, provide a guide for preparing and using HSRs. A shorter, more general guide can be found in “Evolution of Historic Structure Reports at the U.S. National Park Service: An Update” (Biallas, 1977), an APT Bulletin article by Randall J. Biallas, Chief Historical Architect of the U.S. National Park Service. Here, a bulleted list indicates when an HSR is needed, and what information is essential. Biallas states,

“the purpose of an HSR is to record documentary, graphic, and physical information about the history and condition of a structure; to address management or owner objectives; and to record physical work.”

Unfortunately, HSRs continue to be expensive and underutilized. As a guest lecturer in Dr. Nadia Boschi’s course, “Practices of Preservation, Renovation, Reconstruction, and Rehabilitation” (Boschi, 1999), architect Barrett Smith presented a more “user-friendly”, less expensive document. Though it does not entirely replace the HSR, nor is intended to do so, the Documentation of Information (DOI) provides a well-organized reference for various intervention team members to review information throughout an intervention. The DOI is organized in a tabular form, with the following columns listed for each item:

- what was found
- what is thought to be original
• what the team agreed to do with this item
• what was done with the item

The HSR and DOI together provide the most comprehensive documentation of a building’s anamnesis, and should reflect the building’s Statement of Historic Significance.

**FINAL PROJECT OBJECTIVES**

After the Data Collection step has been completed, Final Project Objectives should be established. This requires a review of the Initial Project Objectives, keeping in mind the information gathered in the Data Collection step. Do the objectives:

1. Reflect the Statement of Historic Significance?
2. Allow for compliance with applicable Building Codes?
3. Allow for compliance with Section 106 of the NHPA of 1966?
4. Account for the requirements determined by the Structural Assessment?
5. Account for requirements determined by the Building Performance Diagnosis?
6. Utilize the Anamnesis?

While many of the answers to these questions are reflected in the Project Budget, the Final Project Objectives set the scope of work and establish the focus of the project. Most importantly, the Objectives establish the expected level of quality for the project.

**PROJECT BUDGET**

Much of what drives the structural plan and design in a structural intervention is the budget, for obvious reasons. Yet, like nearly every other aspect of an intervention, the budget cannot be assumed to be handled in the same manner as a normal construction project.

In the article “The Current State of Historic Preservation Engineering: One Engineer’s Point of View” (Fischetti, 1994), engineer David Fischetti shows a fundamental flaw in the way the budget for structural engineering work on an intervention is handled. Like any other project, design fees for a structural intervention are based on how much construction needs to be done, and are based on a percentage of total construction cost.
Additionally, the construction costs need to be set firmly early on in the project, to allow for adequate budgeting. Fischetti argues this often leads engineers to use retrofitted independent structural systems, which basically ignore any capacity the existing structure possesses. By not budgeting for adequate testing and analysis, more intrusive methods are used. Furthermore, extensive analysis and testing might show little or no work needs to be done, but this determination is not in the best interest of the structural engineer, who, as previously stated, is paid based on actual construction that needs to be done.

This lack of foresight in the proportioning of an intervention’s budget remains a problem. Though large budget projects allow for extensive testing and analysis, medium and small-scale interventions still tend to appropriate the majority of their budgets to the Construction phase, and leave the uncertainties of historic materials and construction systems out of the scope of work.

**STRUCTURAL INTERVENTION**

**Structural Intervention Plan**
To create a structural intervention plan, the conservation engineer must determine the structure’s future demand and existing capacity. The first can be established with the guide of local governing building codes, which provide criteria for determining loading. The second is based on the results of the previously performed structural assessment. Further, the plan must reflect the occupancy criteria, compliance with Section 106, needs arising from the diagnosis of the building performance, and project objectives.

**Structural Intervention Design**
By their very nature, structural intervention designs are structure specific, and it is therefore difficult to find a piece of literature that summarizes appropriate systems. The Secretary of the Interior’s Standards for the Treatment of Historic Properties (NPS, 2001) provides guidelines that structural systems must meet to be considered acceptable. Additionally, a great many case studies involving various structural instabilities are available through the APT Bulletin. Structural engineer Stephen J. Kelley’s “Overview:
The Role of the Engineer in Preservation” (Kelley, 1991) provides three such case studies. Furthermore, the article provides a brief synopsis of the elements of structural stability, given below in Table 7. The structural design must address each element to assure structural stability.

Table 7. Summary of Kelley’s elements of structural stability. (Kelley, 1991)

<table>
<thead>
<tr>
<th>ELEMENT</th>
<th>QUESTION</th>
</tr>
</thead>
<tbody>
<tr>
<td>STRENGTH</td>
<td>Can the structure adequately support the imposed loads?</td>
</tr>
<tr>
<td>STIFFNESS</td>
<td>Does the structure deflect excessively?</td>
</tr>
<tr>
<td>STABILITY</td>
<td>Has the structure displaced in an unstable fashion?</td>
</tr>
</tbody>
</table>
CHAPTER 3
STANDARDS OF QUALITY

APPROACH

Often in structural interventions, work is performed that is overly intrusive and damaging to the historic fabric. The effects are generally irreversible, and the final product is a job of sub-standard quality. One way of preventing this type of work from being performed is to begin the project with an appropriate approach. While much of the quality in an intervention is determined by methodology, the approach of the design can set an initial standard of quality for the entire project. Approach affects the quality of a structural intervention on the global level. Specifically, the approach refers to the role of the structural engineer in the intervention design, the assignment of responsibility, and the selection of the intervention team.

THE ROLE OF THE STRUCTURAL ENGINEER

There are two ways an engineer becomes part of a structural intervention. Either an architect plans the intervention, and the engineer is brought in to the project to do an assigned design, or the engineer is on the intervention design team. Either method is acceptable, provided it allows the engineer to fully perform his/her duties, and allows the spirit of the intervention to be reflected in every phase, in every detail, of the work.

ASSIGNMENT OF RESPONSIBILITY

The assignment of responsibility refers to the concept of “continuous accountability”, as presented in Dr. James Woods and Dr. Nadia Boschi’s “Trends and Perspectives in Healthy Buildings in Research and Industry” (Boschi and Woods,1995). Though the concept here refers to the various phases of a structural intervention, rather than the maintenance of a building’s systems, the principles are the same. The three “critical commitments” of continuous accountability are given in the paper as:

1. The identification of the Accountable Person must be explicit at each step in the Continuous Accountability process. This commitment presumes a “Chain-of-Custody” by which accountability can be passed to the appropriate person at the subsequent step in the process. Rather than increasing
professional risk, opinions of both lawyers and insurance carriers have indicated that the actual risk to the Accountable Person will decrease, as the risk is clearly defined in terms of scope and time.

2. The Accountable Person must be empowered with Authority to take the action needed…to provide assurance that the [intervention is being performed] in accordance with the evaluation criteria established at the relevant step of the Continuous Accountability process.

3. The Accountable Person must possess the professional education and training to assure [the intervention is being performed] in accordance with the evaluation criteria established at the relevant step of the Continuous Accountability process.

By adhering to the principles of Continuous Accountability, quality can be clearly linked with an Accountable Person throughout the intervention.

**SELECTION OF INTERVENTION TEAM**

The selection of an intervention team involves the hiring of every team member, from architect to mason. In order to assure quality at this level, it is imperative to select professionals and laborers who will not only do the work assigned to them, but also will recognize the special circumstances involved in a historic intervention and adjust their level of work appropriately. While the work that will be done will affect the intervention on the local level, the determination of what is a “qualified” worker involves the approach to the intervention. By adhering to the NPS’s Standards of Professional Qualifications, quality workmanship can be established in the Pre-Construction phase of the intervention.

**METHODOLOGY**

Once an approach to a structural intervention has been defined, the remainder of the project lies in the methodology. Establishing quality through methodology is done by breaking the project down to the detail level. The project is comprised of four phases, each of which contain a set of steps. Further, each of these steps is associated with a series of tasks, or details. Quality is most readily established and controlled at this level. Figure 1 demonstrates the hierarchy of the intervention and the corresponding effect of quality.
The practical aspects of quality are controlled at the local level. Specifically, each detail is analyzed and the best available approach utilized. Below is a summary of each step from Table 1, and the details within each step. This summary lists each detail, defines it, and establishes quality for that detail.

**INITIAL PROJECT OBJECTIVES**

Before data collection can begin, initial project objectives must be established. As indicated in Chapter 2, this involves creating a general scope of work for the project and focusing on what the building will be used for when the intervention is complete. While the initial project objectives do not need to be detailed (and can not be, as the data collection is not yet complete), the purpose of the intervention must be clearly defined to provide a scope of work for the step of Data Collection.
DATA COLLECTION

Statement of Historic Significance

The Statement of Historic Significance defines what makes a property historically significant and what features are historically significant. To attain a quality Statement of Historic Significance, first and foremost the data collected must be accurate and proven. Extensive documentation must be assembled which clearly addresses all three steps – the property’s historic context, criteria for historic significance, and degree of authenticity. Additionally, this documentation should provide a physical description of the property, as well as the property’s geographic location and boundaries.

Historic context, as defined in Chapter 2, establishes the scale on which the structure is historically significant. A structure could be of importance within a culture, or part of a theme that carries across cultures. The “National Register Bulletin: Guidelines for Evaluating and Nominating Properties that have Achieved Historic Significance within the Past Fifty Years” (National Register, 1998) further states,

“In evaluating and justifying exceptional importance, it is especially critical to identify the properties in a geographical area that portray the same values or associations and determine those that best illustrate or represent the architectural, cultural, or historical values being considered.”

Therefore, establishing quality in the historic context involves clearly defining how the property fits into the geographical area within its historical theme.

The criteria for historic significance establish why a structure is a historic contribution. To be considered historic, a structure must meet at least one of the National Register’s four criteria, presented in the “National Register Bulletin: Guidelines for Evaluating and Nominating Properties that have Achieved Historic Significance within the Past Fifty Years” (National Register, 1998), and are summarized in Table 8. Establishing quality in the criteria for historic significance involves determining which of the criteria the property qualifies, and providing required documentation of proof.
The third and final step in establishing a structure’s historic significance is the authentication of the building. The intent of any intervention is to accurately depict some aspect of a property as it was either originally constructed, or at least originally intended to be. Therefore, without authenticity, there is no level by which to measure the work of the intervention. What is to be deemed “historically significant”, if there is no authentication of what is actually historic? Authenticity, as outlined in Table 5, is measured by the property’s reflection of its true value, integrity, context, identity, and use/function. A quality authentication investigates each of these indicators, and utilizes them to measure the level of authenticity of the property.

**Compliance with Building Codes**

Though all construction must comply with the applicable model code requirements, historic properties undergoing an intervention are subject to three requirements in particular: occupancy criteria, accessibility requirements, and disaster mitigation codes.

The occupancy criteria of a building consist of the existing certificate of occupancy and the planned use of the building after the intervention. If the building is going to undergo a change of use or a change of occupancy, the changes must be approved by the local building official. Establishing quality at this level involves clearly defining the intended use of the structure, and attaining the appropriate certificate of occupancy.
As previously stated, the accessibility requirements of a building are determined by the ADA (Americans with Disabilities Act of 1990). Historic properties are subject to less restrictive regulations, but still must comply with these requirements. The Secretary of the Interior’s Standards for the Treatment of Historic Properties (Code, 1995) gives the best synopsis of quality for this detail as follows:

“Work must be carefully planned and undertaken so that it does not result in the loss of character-defining spaces, features, and finishes. The goal is to provide the highest level of access with the lowest level of impact.”

Disaster mitigation is a “life, health, and/or safety” issue, and must be given the greatest of considerations in a structural intervention. However, retrofitting a structure for seismic or hurricane issues should not be done without understanding the existing structural system of the property. A number of unreinforced masonry buildings from the early 1900s in seismic zones were retrofitted in the 1960s with reinforced concrete members. These structures failed during the next earthquake because they had been made too stiff, and could not handle the seismic loads. Therefore, to assure quality in this element of an intervention, a detailed analysis should be conducted to determine:

- What levels of seismic and/or hurricane loads must the structure resist?
- What is the structure currently capable of resisting?
- How is the structure currently resisting these loads?
- What can be done to supplement this system to upgrade the structure?

Compliance with Section 106

Complying with Section 106 of the National Historic Preservation Act (NHPA) of 1966 means utilizing intervention philosophies and methods that are acceptable under the standards and guidelines of the NACHP (National Advisory Council on Historic Preservation). The most readily available way of establishing quality at this level is to have a clear understanding of the acceptable intervention philosophies and methods, and how they should be applied in practice.
Structural Assessment

The structural assessment of a building entails the analysis of a building’s structural systems and materials to determine the structural integrity of the building. This involves materials testing and a physical investigation, as well as a computational analysis, as described previously in Chapter 2.

The physical investigation should provide information on the structural system of the property. The materials testing should reveal the state of integrity of the structural materials of the property; the structural analysis should provide a measurable load capacity of the system as built. A quality structural assessment uses the least intrusive methods of analysis that are financially feasible to provide accurate data on the stability of a building, and provide adequate information to develop the structural design.

Diagnosis of Building Performance

The diagnosis of a building’s performance, as it relates to structures, is an assessment of the efficiency of the building’s structural system; an analysis of whether any hazardous materials make up this structural system; and a determination of the system’s probable rate of decay. A quality building diagnosis clearly defines the existing state of each of the building’s systems and provides a probable rate of degradation for each of these systems. This diagnosis is used to develop the intervention plan, as it provides data on the existing state of the structure.

Anamnesis

An anamnesis provides a building’s history. Blueprints, surveys, and written accounts may all be used to establish when additions or alterations were made to the structure, and why. A quality anamnesis is a complete documentation of the evolution of a building. Additionally, a quality anamnesis is completed in such a way that it may be useful to the intervention planners by providing specific information about historic elements, and how they relate to the structure as a whole.
**Final Project Objectives**

By using information gathered through Data Collection, the Initial Project Objectives can be expanded to a detailed list of Final Project Objectives. These new objectives reflect:

- the purpose of the intervention
- the requirements of the building codes
- the diagnosis of the building performance
- the structural assessment

Quality can be established at this level by developing Initial Project Objectives into Final Project Objectives that are realistic, clearly defined, and reflect all the required and desired results of the intervention.

**Project Budget**

Based upon Final Project Objectives and available finances, a project budget is established. This budget includes an overall figure, as well as a breakdown of the budget for the major contracts, including structural work. Quality, time, and money are the three major factors that must be balanced in any project. Recognizing that they are directly proportional, a quality budget is therefore flexible enough to allow for change orders, the hiring of qualified professionals and laborers, the use of quality materials, and the time it takes to perform a job that meets the standards of quality established in the Final Project Objectives.

**Structural Intervention**

**Structural Intervention Plan**

The structural intervention plan defines the requirements of the structural design. The plan should be one of, or a combination of, the four categories introduced by Ghassan Attar, namely stabilization, consolidation, rehabilitation, or reconstruction. A quality plan is one that makes efficient use of the existing structure, while providing for the future needs of the structure.
**Structural Intervention Design**

A structural design usually involves schematic designs of two or three different options, then a full design of the best of these options. The design should represent the culmination of all the information assembled in the Pre-Construction phase. The Project Objectives, Compliance with Building Codes, Compliance with Section 106 of the NHPA, Structural Assessment, and Diagnosis of the Building’s Performance all affect the Structural Intervention Plan. The design itself must consider this Plan, the Project Budget, and, through the Anamnesis, the Statement of Historic Significance. Furthermore, a quality Structural Intervention Design utilizes the least invasive procedures to provide a stable structural system, while fully addressing the issues of strength, stiffness, and stability.
Based on information gathered in the literature review, and the previously established standards of quality, this chapter presents a series of quality control recommendations for a structural intervention. These recommendations are general, and cannot be applied without considering the specific needs of a particular project. However, these recommendations are intended to be applied to an intervention of any size. Those recommendations that are affected by the project budget are specifically called out, and different options are presented for smaller and larger budget interventions.

**APPROACH**

As previously mentioned, the approach of the design can set an initial standard of quality for the entire project, as it affects quality on a global level. In general, the following recommendations assure that quality control is not left to be done only on the local level. By establishing it on every level, quality can be assured. The recommendations first address the approach on a general level, then deal with the specific issues of: the role of the structural engineer in the intervention design, the assignment of responsibility, and the selection of the intervention team.

**GENERAL RECOMMENDATIONS**

**A Holistic Approach**

The first means of establishing quality in an intervention is the utilization of a holistic approach. A holistic approach - recognizing how each aspect of the work affects all the others - prevents the intervention plan scheduling work in an improper order and work being repeated. Additionally, this assures historic elements will not be left unprotected and will not be damaged. Taking a holistic approach to the intervention requires a detailed plan of work. By reviewing all of the proposed work systematically, the results of each step can be easily seen. Thus, the consequences and effects of each step of the intervention can readily be perceived, and prepared for.
SPECIFIC RECOMMENDATIONS

The Role of the Structural Engineer
A structural engineer is typically in one of two roles in a historic intervention. The first, and most common, is as a subcontractor to the architect. The second is as a prime consultant on the project. While either role may allow for adequate testing, analysis, planning, and design, the second allows for more flexibility in the final structural intervention design. Because of their specialized knowledge, engineers can offer design alternatives that are cost efficient, and pose less of a threat to the property’s historic fabric. Further, including the structural engineer as a prime consultant on the intervention design team assures that the philosophy of the intervention will be reflected in the structural design, and the engineer is fully aware of limits within which the design must fall.

Assignment of responsibility
Having one Accountable Person in charge of quality control throughout the entire intervention would seem at first glance to be the best way of assuring continuous accountability. This Accountable Person would be clearly identified (meeting the first criteria of continuous accountability), and would be empowered with the authority to take necessary action to assure quality (meeting the second criteria of continuous accountability). However, no one person can possess all the education and training necessary to oversee every step of a historic intervention. Therefore, continuous accountability must be established through a series of Accountable Persons, each clearly identified, empowered with the authority to take action, and educated and/or trained in their respective field.

Additionally, this establishment of continuous accountability must take place in the Pre-Construction Phase. Failing to predetermine the team member responsible for assuring quality at each stage of the work can, and will, lead to large gaps in quality control, and therefore gaps in quality, within the intervention. Additionally, waiting until the Construction Phase means having quality control principally monitored on the local level, by laborers and subcontractors. By designating, in the Pre-Construction Phase,
one intervention team member per step to assure quality, these potential gaps in quality control will be eliminated.

**Selection of the intervention team**

As previously mentioned, the National Park Service has a publication called the “Proposed Historic Preservation Professional Qualification Standards” (NPS, 1997), which gives detailed descriptions of “qualified” professionals in various fields, including engineering. Strict adherence to these standards is only necessary when hiring a professional to serve as prime consultant on a federal-grant assisted contract. However, these requirements may be used as a guideline for other projects. As a preface to the actual standards, the document provides *Discipline and Historic Preservation Proficiencies*, a series of general proficiencies related to discipline and historic preservation.

Another recommendation in the selection of the intervention team is to inform all on-site workers of issues concerning historic interventions. Because the standard of quality in a historic intervention is so different from other types of construction, simple ignorance of acceptable practice can cause a failure of quality control. By recognizing the affect of every professional and worker on the project as a whole, the need to see the intervention as an interconnected set of jobs, rather than a series of related but unconnected jobs, becomes even more apparent. Simply defining the standard of quality for a historical structural intervention to all workers can avert many of the quality issues that can occur in an intervention.

**METHODOLOGY**

The methodology of an intervention involves the practical steps of each phase. At this local level, quality control recommendations provide guidance on the method of conducting each step that is most likely to achieve the previously established standard of quality. These recommendations follow the format of the previous chapters, addressing each of the steps in the Pre-Construction phase, and any details included in
these steps, as listed in Table 1. Further, they establish the team member responsible for each step.

**INITIAL PROJECT OBJECTIVES**

Initial Project Objectives are set by the owner and the intervention design team. They should reflect intervention philosophies and practices, as well as the owner’s planned use of the property. By clarifying these issues at the beginning of the project, quality may be defined for the rest of the project. Furthermore, these Objectives should provide a clear scope of work for the Data Collection step of the Pre-Construction Phase in order for all the data necessary for the intervention to be gathered. This data must be clear to create a quality structural intervention design that responds to structural deficiencies without damaging the historic fabric of the property.

**DATA COLLECTION**

**Statement of Historic Significance**

The Statement of Historic Significance should be made by a conservator or architectural historian. These professionals can not only accurately identify historic elements, but also understand the purpose of the Statement and its intended use. The Statement should be a clear account of the historically significant elements of the property, and provide documentation of historic context, applicable criteria of historic significance, and authenticity, for each element. This must be clearly defined so that all members of the intervention team understand the parameters of the project.

**Compliance with Building Codes**

To comply with building code requirements for occupancy criteria, ADA regulations, and disaster mitigation, two primary steps to be carried out by the intervention architect are recommended. First, a copy of the applicable local building code should be obtained. Second, the local building official should be consulted as to what level of compliance is required for the intervention. Because the section of most building codes that deals with interventions (alterations to existing buildings) is vague, the local
building official has quite a bit of discretion in determining what level of compliance a given intervention must meet. By speaking with the building official early in the project, code requirements can be easily included in the intervention plan and design.

**Compliance with Section 106 of the NHPA**

The *intervention design team* should consult Section 106 of the NHPA to first determine if the intervention falls under the law. If the project is not on the National Register of Historic Places, or eligible for placement on the Register, and/or managed by a federal agency, Section 106 does not apply. Otherwise, the intervention plans must be submitted to the National Advisory Council on Historic Preservation (NACHP) for review. These plans should provide thorough documentation of the Statement of Historic Significance, as well as comply with accepted intervention philosophies and practices.

**Structural Assessment**

The structural assessment includes the *structural engineer's* physical investigation, materials testing, and structural analysis of the property. As indicated in the literature review, the quality control recommendations for structural assessment include utilizing Rabun’s methods of assessment (Rabun, 2000). These tables provide guidance for the method of conducting a structural assessment. The majority of the included steps are self-explanatory. Two steps in the Phase Two Assessment are, however, more involved, and therefore require separate quality control recommendations. These steps, *materials testing* and *development of the mathematical model*, were discussed in detail in chapters 2 and 3.

*Materials testing* consists of destructive and non-destructive (NDT) methods. Destructive testing methods are acceptable when they result in limited impact on the historical integrity of the property. The impact of such tests is best determined by a review of the Statement of Historic Significance, which would indicate what elements of the property have been deemed historic. NDT methods can be expensive, and budgetary constraints should be considered in determining their use. Another consideration in the selection of
material testing is the investment vs. return. The engineer must determine how crucial the results of the testing are to the structural design. Utilizing Table 6 and the Statement of Historic Significance, a decision can be made as to which testing method is most appropriate for the intervention.

*Mathematical modeling,* as part of the structural assessment, provides hard numbers on the capacity of the existing and future structural systems. Commercially available finite element modeling computer programs provide extensive results with great accuracy. They are, however, only reflections of the data that was entered into the model initially. In other words, the results are only as accurate as the given data. Another important issue with computer modeling is the relationship between the model and the actual structure. The more faithfully the model represents actual conditions, the more accurate the results will be. Finally, many modeling programs have evolved to very simple user interfaces. This can be deceptive, allowing the user to input data without questioning the program’s assumptions or conventions. Therefore, the recommendation for mathematical modeling is to first create a simple computer model of the structure, and then check the results with hand calculations (i.e., equilibrium checks). When the results of the computer and hand calculations agree, the computer model should be modified one step at a time until it is a realistic model of the actual structure.
Diagnosis of Building Performance

As stated in chapter 3, the diagnosis of a building’s performance, as it relates to structures, is an assessment of the efficiency of the building’s structural system; an analysis of whether any hazardous materials make up this structural system; and a determination of the system’s probable rate of decay. This diagnosis, done primarily by the *structural engineer*, is used to develop the intervention plan, as it provides data on the current state of the structure.

The presence of hazardous materials in a structural system is most easily tracked by the era in which the structure was built, and any alterations made. The original construction period of the property, and that of any recorded alterations, can be found by referencing the documentation of the Statement of Historic Significance. The physical investigation of the property in the structural assessment indicates if hazardous materials are present in the structural system, through materials testing. This is when the rate of decay of the structural system is also determined, as it is most dependent upon the materials. Some “decay” of the system can occur over time due to cyclic loading, which may weaken some connections in the system. These weaknesses can best be determined by reviewing the loading the structure sees on a regular basis, and by visual analysis during the physical inspection.

The efficiency of the structural system is best determined through the structural analysis. The analysis should involve mapping the load paths of the system, which indicates if members are carrying more or less than their share of the load. Further, load paths will indicate a building’s level of structural integrity. This is a measure of how interdependent the various structural elements are. Ideally, a structure that fails in one area will not cause the entire building to fail, which is known as progressive collapse. A building of high structural integrity will have redundancies, but this does not reduce the efficiency of the structural system.

Anamnesis

Because the information assembled in the anamnesis is crucial to the quality of the intervention design, the quality of the anamnesis is crucial. The anamnesis provides a
key link between the Statement of Historic Significance, the Intervention Plan, the Intervention Design, and, eventually, the Construction Phase. Many smaller projects do not use, nor do they need, a full scale Historic Structure Report (HSR). But without any written form of anamnesis, the project loses cohesion, and quality becomes piecemeal. Therefore, the use of a Documentation of Information (DOI) is recommended for every project, large or small. Large projects will have an HSR as well, but the DOI tends to be easier to utilize in the Construction Phase, where the danger to the historic fabric is greatest. Small projects can utilize a DOI as a means of recording specific data about historic elements and sharing this information with the members of the intervention team in the Construction Phase.

**FINAL PROJECT OBJECTIVES**

Final Project Objectives should be realistic, clearly defined, and reflect all the required and desired results of the *owner* and the *intervention design team*. Because the Intervention Plan is designed to accomplish these Objectives, they are a critical link between the Data Collection step and the Intervention Plan. Therefore, the standard of quality in the Objectives will be directly linked with the quality of the Intervention Plan. The recommendation for this step is to create a written set of project objectives, and to make sure that each team member’s scope of work is designed to accomplish these objectives.

**PROJECT BUDGET**

As established in chapter 3, the budget for a structural intervention is generally managed in the same manner as a regular construction project, which drives the structural engineer to use, often unnecessarily, independent retrofit systems that supercede the existing system. The alternative is to provide for the testing and analysis of the existing system, as well as any upgrades that may be required. Both options can, if appropriately handled, result in a property that is structurally stable and retains its historic integrity. The key differences are the overall cost and the ease with which they are “appropriately handled”.
An independent retrofit system is extensive, and must, by design, affect every part of the property, as it is designed to carry all the load of the structure. The sheer size of these systems (relative to the majority of those systems designed to work with the existing structure) increases the odds of damaging the historic fabric. Further, it renders the original structure useless, which in itself damages the historic integrity of the property. By utilizing the existing capacity of the structure, a lesser intervention is generally required, which has less chance of damaging the historic fabric. Further, it allows the structure to work as was originally intended, which is an element of historic integrity.

The results of materials testing and structural analysis can often indicate little or no work needs to be done. This causes some owners to question what they’ve paid for. General consensus seems to be that the budget should be spent on actual construction, not investigation. Moreover, materials testing and structural analysis can be expensive. All this leads many owners and intervention design teams to decide to skip the in-depth assessment, save some time and money, and plan on an independent retrofit. But, in many cases, advanced structural assessment can save time and money. In Silman’s article on NDT (Silman, 1996), the author presented a case study of some marble columns at Princeton University. These historic columns, dating from 1893, were tested using standard coring methods and results were inconclusive, leading to the presumption the columns would have to be replaced. NDT was done using impulse radar, and showed the columns to be safe. Replacing the columns would not only have destroyed original historic elements of the property, it would have cost the University more than $750,000. The radar scanning, interpreting, and reporting was $10,000.

The recommendation, therefore, is to allow for advanced structural assessment, including materials testing and structural analysis, in the budget.
**Structural Intervention**

**Structural Intervention Plan**

The Structural Intervention Plan is an accounting of the existing capacity of the structure, and the required capacity for future use. To control the quality of the intervention at this stage, the *structural engineer* should ensure that the plan:

- Reflects the intent of the Statement of Historic Significance
- Meets all federal, state, and local building regulations
- Fulfills the requirements of Section 106 of the NHPA
- Clearly establishes the existing capacity
- Clearly establishes the required future capacity
- Responds to the Final Project Objectives
- Meets budgetary constraints

**Structural Intervention Design**

The Structural Intervention Design is a direct result of the Structural Intervention Plan. Though the design itself is structure specific, there are general recommendations to control quality. The design should:

- Reflect the Structural Intervention Plan
- Make use of the existing capacity of the structure
- Upgrade the structure to the required future capacity (for strength, stiffness, and stability)
- Utilize one of or a combination of Attar’s four approaches to structural intervention
- Offer the least invasive means of stabilizing the structure
**SUMMARY OF QUALITY CONTROL RECOMMENDATIONS**

<table>
<thead>
<tr>
<th>APPROACH</th>
<th>Methodology</th>
</tr>
</thead>
<tbody>
<tr>
<td>Use a holistic approach</td>
<td><strong>INITIAL PROJECT OBJECTIVES</strong></td>
</tr>
<tr>
<td>Contract the structural engineer as a prime consultant</td>
<td>Set by the <em>owner</em> and the <em>intervention design team</em></td>
</tr>
<tr>
<td>Continuous accountability must be established</td>
<td>Reflect intervention philosophies and practices, planned use of the property</td>
</tr>
<tr>
<td>through a series of Accountable Persons, each clearly</td>
<td>Provide a clear scope of work for the Data Collection step</td>
</tr>
<tr>
<td>identified, empowered with the authority to take</td>
<td></td>
</tr>
<tr>
<td>action, and educated and/or trained in their</td>
<td></td>
</tr>
<tr>
<td>respective field</td>
<td></td>
</tr>
<tr>
<td>Reference the “Proposed Historic Preservation</td>
<td></td>
</tr>
<tr>
<td>Professional Qualification Standards”</td>
<td></td>
</tr>
<tr>
<td>Inform all on-site workers of issues concerning</td>
<td></td>
</tr>
<tr>
<td>historic interventions</td>
<td></td>
</tr>
</tbody>
</table>

| STATEMENT OF HISTORIC SIGNIFICANCE                    | **COMPLIANCE WITH BUILDING CODES**   |
| Made by a *conservator* or *architectural historian*   | Carried out by the *intervention architect* |
| Clear account of the historically significant        | Comply with building code requirements for occupancy criteria, ADA regulations, and disaster mitigation guidelines |
| elements of the property                              | Consult local building official       |
| Provide documentation of historic context, applicable |                                      |
| criteria of historic significance, and authenticity, |                                      |
| for each element.                                     |                                      |

| **COMPLIANCE WITH SECTION 106**                       | **STRUCTURAL ASSESSMENT**             |
| Determined by the *intervention design team*          | Managed by the *structural engineer*  |
| Determine if the intervention falls under the law     | Follow Rabun’s guidelines for Assessment |
|                                                     | Consult Table 6 to determine best materials testing option |
|                                                     | Utilize computer modeling, check with hand calculations |

| **DIAGNOSIS OF BUILDING PERFORMANCE**                 | **ANAMNESIS**                         |
| Determined by the *structural engineer*              | Created by the *architect*            |
| Refer to data collected during physical investigation | Create a Documentation of Information (DOI) |
| and materials testing, as well as historical data    |                                      |
| providing information on the building’s past         |                                      |
| performance                                         |                                      |

| **FINAL PROJECT OBJECTIVES**                          | **PROJECT BUDGET**                   |
| Established by the *intervention design team*         | Established by the *intervention design team* |
| Write specific project objectives, indicating team    | Provide adequate budget for structural survey, analysis, and materials testing |
| member responsible for each objective                 |                                      |

| **STRUCTURAL PLAN**                                   | **STRUCTURAL DESIGN**                |
| Created by the *structural engineer*                  | Created by the *structural engineer*  |
| Establish structural intervention philosophy, and     | Utilize existing capacity with        |
| existing and future capacities                        | accepted structural intervention     |

| **Table 9. Quality Control Recommendations**          |                                      |
|                                                     |                                      |
CHAPTER 5
CASE STUDY: BOYKIN’S TAVERN

Figure 2. Boykin’s Tavern, Isle of Wight, Virginia (Isle of Wight, 2002)

Boykin’s Tavern is a two-and-a-half story wooden structure built in the mid-eighteenth century in Isle of Wight, Virginia. Originally a hotel and tavern, and later part of the Isle of Wight county Courthouse, the Tavern was placed on the National Register of Historic Places in 1974 for its historical and architectural feature (NPS, 1974). In 1999, the Tavern’s owner, Isle of Wight County, decided to renovate and reopen Boykin’s Tavern.

THE INTERVENTION
INITIAL PROJECT OBJECTIVES

Isle of Wight County, the owner of Boykin’s Tavern, wanted to renovate and reopen the Tavern as a community center, with space for a visitors’ center, a conference area, and a museum exhibit area. This involved a change of use for the property, which had been vacant for over twenty-five years. The mechanical, electrical, and plumbing (MEP) systems needed to be upgraded to meet Building Code requirements. Furthermore, the structure had been deteriorating for some time and required extensive work to meet the Building Code requirements. The change of use, in combination with the required upgrade of the MEP and structural systems, meant that the project would be a historic rehabilitation.
After a competitive bid of qualified architects, the project was awarded to Paul Hardin Kapp, of Galax, Virginia. Kapp contracted David A. Ross of Independence, Virginia, as the project’s structural engineer, and Virtexco Corporation of Norfolk, Virginia, as the prime contractor for the project. Both the architect and the contractor were experienced with historic rehabilitations. Given the County’s needs, and the guidelines for a historic rehabilitation, the architect and structural engineer assessed the property to determine the required changes.

DATA COLLECTION

Statement of Historic Significance

Utilizing the Tavern’s 1974 nomination from for the National Register of Historic Places (NPS, 1974), the architect was able to clearly identify the property’s historically significant features.

Historians believe the tavern was originally constructed as a center-hall structure that was one-and-a-half stories high. Two major renovations were performed on the building, the first in the early 1800’s, and the second in the early 1900’s. As submitted in the nomination form for the National Register of Historic Places in 1974,

“The first additions, including the elevation of the main block to two stories and a one-and-a-half story frame gambrel roof wing, were built in the early nineteenth century. In 1900-1902 Boykin’s Tavern received numerous repairs and alterations including the present porch, a second two-story frame wing and some interior remodeling.” (NPS, 1974.)

The tavern was placed on the National Register of Historic Places in 1974 for its historical and architectural features. Historically, it was the location of the Isle of Wight Courthouse in 1800. In addition, the tavern’s original owner, Francis Boykin, was an important figure in the history of Isle of Wight County. Architecturally, Boykin’s Tavern represents a mix of the Colonial and Federal styles. Its most prominent architectural features are on the interior, however. The first and second floor north side rooms still possess their original woodwork. The wall panels and chimney mantels in the northeast corner are original as well. The most historically important interior features are in the northwest rooms, where an ornate chimney mantel and a cornice with
Wall-of-Troy molding, which is quite rare in public buildings in Virginia, are located. (NPS, 1974.)

Compliance with Building Codes

In 1999, the Isle of Wight County Building Code was based on the 1996 BOCA model code. The applicable section of the code to the Tavern was Chapter 34, Existing Structures. Section 3404.2, Alterations, states in part,

“An alteration to any structure shall conform to the code requirements for a new structure…Portions of the structure not altered and not affected by the alterations are not required to comply with the code requirements for a new structure.” (BOCA, 1996).

Yet because of the Tavern’s National Register status, Section 3406.0, Historic Structures, supercedes this, stating,

“The provisions of this code relating to the construction, repair, alteration, addition, restoration and movement of structures shall not be mandatory for existing buildings and structures identified and classified by the federal, state or local government authority as historic buildings where such buildings are judged by the code official to be safe and in the interest of public health, safety and welfare regarding any proposed construction, alteration, repair addition and relocation.”

Therefore any and all proposed alterations by the structural engineer and/or architect were not subject to the more stringent requirements of a new structure, as stated in Section 3404.2, but needed only to be judged safe by the building code official.

Compliance with Section 106 of the NHPA

Section 106 did not apply to the Boykin’s Tavern rehabilitation, as it did not involve a federal agency.

Structural Assessment

In 1999, Boykin’s Tavern was a 5300 square foot, 2½ story wooden braced-frame structure supported on brick foundation walls, with five exterior chimneys (see Figure 3). The original construction was mortise and tenon, with hard pine throughout. The foundation consisted of 8 in. brick walls on 20 in. continuous masonry wall footings.
With no as-built drawings or record of previous alterations, the structural engineer was entirely reliant on his survey of the structure. Utilizing small cut-outs in the floor sheathing, and removing some portions of plaster and lath on the walls, the general size, location, and condition of the framing was established. Given the framing of the structure, materials testing was not warranted. The survey was sufficient enough to establish that additional capacity would need to be introduced to meet the demand of the structure’s new use, so a computational model was left until the structural design phase.

Diagnosis of Building Performance
While the engineer’s survey of the framing yielded no hazardous building materials, the roof and some of the walls were found to be in need of abatement. Due to the property’s age and the number of years it was left vacant and not maintained, the structure was in an advanced rate of decay. Though the majority of the foundations, the exterior walls, and the majority of the second floor sheathing and framing were in adequate to good condition, there were local areas that were failing, or had already failed. Many of the first floor joists were rotten, the second floor northwest corner had been destroyed by rot and termites, the roof was failing, and all five of the chimneys were in various stages of separating from the building.

Anamnesis
Due to the size and scope of this intervention, an HSR was not warranted. An accounting of the Tavern’s historically significant elements and features was incorporated into the project’s Design Manual.
**Final Project Objectives**

Because the majority of the information gathered in the Data Collection step was structural in nature, the Initial Project Objectives did not change, but were simply outlined in more detail, providing specific information on what structural elements would need to be repaired or replaced, and a projected date of completion for the project of December 2000.

**Project Budget**

Based on the Final Project Objectives, a Project Budget of nearly $1 million was set. This was intended to cover all the structural repairs, alterations, and additions, hazardous material abatement, MEP upgrades, and architectural interiors and finishes.

**Structural Intervention**

**Structural Intervention Plan**

Given that the project had been established as a historic rehabilitation, the structural intervention plan called for a structural consolidation, which is

> “Improving the condition of existing materials and systems. This usually involves the introduction of new materials or construction methods.” (Attar, 1991)

To satisfy the criteria of the Building Code, the structure needed to upgrade the capacities of the first and second floors to support the new occupancy loading requirements. Additionally, the chimneys needed to be stabilized, the roof replaced, and a new addition to the structure made to allow for the plumbing upgrades.

**Structural Intervention Design**

The structural intervention design began with the roof. Several members were rotting due to leakage, and had to be replaced. In an effort to stiffen the diaphragm of the roof, a number of new members were added.

The first and second floors were strategically strengthened by:

- Replacing rotted or termite damaged joists
• Sistering heavily loaded and/or long-span joists with steel channels (See Figure 4)
• Reducing joist spans to 16’ or less with the introduction of steel channels as girders

The steel channels served to increase capacity, as well as decrease deflection. The existing flooring (3 layers thick in some areas) was retained where possible, as it was determined to provide an adequate shear diaphragm.

Figure 4. 2nd floor, northwest corner, channels sistered with joists.

The walls of the tavern were constructed of hardwood timbers and covered with lath and plaster. They were determined to be adequate to sustain the new loading. During the intervention, the lath and plaster were completely removed from the exterior walls to allow for the addition of insulation and wiring. While this temporarily reduced the capacity of the walls to transmit shear, the lath and plaster were replaced in the permanent condition.

Before the intervention, the building’s five chimneys were in various stages of separating from the building, as they were completely external to the outer walls of the structure. Signs of weathering and material degradation were visible in the crumbling masonry at the chimney tops and the holes left by missing bricks. Recreating a solid connection between the chimneys and the building was important to the stability of the structure, as
well as the historic fabric. The chimneys were anchored to the structure along the exterior walls at the 2nd floor, attic floor, and roof with two steel rods threaded at each end. Steel strapping channels were run along the portion of the chimneys that extended beyond the roof, and anchored to the roof framing with steel angle braces (see Figure 5).

![Figure 5. Chimneys of Boykin’s Tavern under repair (Virtexco, 1999).](image)

The existing foundation consisted of 8 in. brick walls on 20 in. continuous masonry wall footings. While the walls and footings were generally in good condition, they were insufficiently sized to carry the new loading of the structure. Furthermore, without materials testing, the strength of the bricks and mortar could not be definitively established. New 24 in. by 24 in. concrete footings and 8 in. masonry foundation walls were therefore added to supplement the existing foundations.

The new addition is a one story, wood braced-frame system framed into the back (north) wall of the structure at the 2nd floor (see Figure 6). To keep the building historically accurate, an earlier addition of a back porch was removed. The porch had been insufficiently tied into the back wall of the Tavern and was pulling away from the original structure.

![Figure 6. New addition to the back of Boykin’s Tavern (Virtexco, 1999)](image)
LESSONS LEARNED

The intervention of Boykin’s Tavern called for a historic rehabilitation and a structural consolidation. The majority of the work done was in keeping with the intent of rehabilitation and consolidation. The removal of the newer back porch and construction of the new addition were both accepted practices in rehabilitation, as were the repapering of the roof and the treatment of the floors. The use of new members and introduction of new steel girders, the sistering of existing members with steel channels, and the addition of supplemental foundation elements were all acceptable techniques in structural consolidation. However, the use of channels along the chimneys was damaging to the historic fabric of the structure. The Secretary of the Interior’s Standards for Rehabilitation expressly lists the installation of strapping channels to upgrade the building structurally as not recommended (NPS, 2001).

**Not recommended:**
Upgrading the building structurally in a manner that diminishes the historic character of the exterior, such as installing strapping channels.

While the chimneys needed to be strengthened and adequately tied to the structure, the use of steel channels should have been avoided, and another option investigated. FEMA’s Earthquake Hazard Mitigation Handbook (FEMA, 2002) provides three options for securing chimneys to a structure:

- Chimney extensions above the roofline can be secured with steel straps anchored to the roof framing with steel angle braces.
- The chimney flue enclosure can be reinforced using vertical and horizontal bars encased in concrete.
- For multi-storied buildings, chimneys can be anchored at each floor level using steel wrap ties that are anchored to the floor joists.

Given the Standards for Rehabilitation’s recommendation against strapping channels, one of these other options should have been utilized.

In conclusion, the structure of Boykin’s Tavern is stable, but the historic fabric was compromised. This could have, and should have, been addressed in the Pre-Construction Phase. Some potential reasons for this break-down in quality control are:
• The structural engineer was not familiar with the accepted practices of structural consolidation.

• The project budget did not allow for the analysis or construction of one of the alternatives for securing the chimneys.

• The Statement of Historic Significance was not clearly reflected in the final project objectives.

Whatever the source of the break-down, an adequate quality control system, similar to that presented in chapter 4, would have sufficient redundancies in accountability and project objectives that the potential threat to the historic fabric would have been recognized, and possibly avoided.
In 1995, concerned for the structural stability of Fallingwater, the Western Pennsylvania Conservancy (the trustees of Fallingwater) commissioned the structural engineering firm of Silman & Associates to conduct a structural investigation.

THE INTERVENTION

INITIAL PROJECT OBJECTIVES

The scope of work of the structural investigation included the determination of the strength, stiffness, and stability of the terraces of Fallingwater. Notably, these Initial Project Objectives did not call for an intervention, but an investigation.

DATA COLLECTION

Statement of Historic Significance

Because Fallingwater was designed by renowned architect Frank Lloyd Wright, it was architecturally significant even when it was first constructed. Aside from the designer, the structure is significant, not only architecturally but also structurally and historically, for its cantilevered terraces. Documentation of Wright’s original intent for the structure, including letters to the original owner and the original structural engineer, notes,
photographs, and drawings were collected to create the Statement of Historic Significance.

**Compliance with Building Codes**

Under the Initial Project Objectives, there was no intended change of use, or intent to alter or repair the structure, so there were no Building Code requirements.

**Compliance with Section 106**

Section 106 did not apply to the Fallingwater investigation, as it did not involve a federal agency.

**Structural Assessment**

The structure of Fallingwater is a combination of reinforced concrete and stone. The terraces are each comprised of four reinforced concrete beams (some spanning nearly 20 ft.) with 4 in. concrete joists spanning between. Beneath the beams is a concrete slab, creating an inverted T-beam (Silman, 2000).

Reinforced concrete was still a relatively new material in 1936, and its limits had not been tested fully. This led to the insufficient structural design of the cantilevered terraces of Fallingwater. Wright’s engineer cautioned him that his cantilevers required more reinforcing steel, but Wright continued with his design. The engineer placed twice the amount of steel in the cantilevers than Wright called for originally, but it still wasn’t enough (Silman, 2000). The first floor cantilever had an instantaneous deflection of nearly two inches when the forms were removed. By 1997, the master terrace had deflected nearly seven inches (Silman, 2000).

To accomplish the Initial Project Objectives, Silman & Associates performed three tasks: a physical investigation, materials testing, and computer modeling. First, using a level, and consulting previously conducted deflection surveys, the deflections of the terraces were measured and recorded. An “in-service structural monitoring system” was installed to gather deflection data. Impulse radar, ultrasonic pulses, and high-resolution
magnetic detection were then utilized to verify the quantity and locations of the reinforcing bars, as well as the soundness of the concrete. Finally, a computer model of Fallingwater was created using the finite element program SAP90 to determine the capacity of the existing system, and to establish the load paths of the system (see Figure 8). The results of this model were checked with some known quantities, such as measured deflections and yield stresses of sample reinforcing bars (Silman, 2000).

![Figure 8. Bending stress contours from SAP90 model of Fallingwater’s Master Terrace (Silman & Assoc, 1996).](image)

**Diagnosis of Building Performance**

The structural analysis indicated that the building’s structural performance was inadequate, as it was not meeting the required loading demand. Historic documentation indicated no hazardous materials were present. Utilizing past records of deflections in combination with the results of the structural analysis and physical investigation, a rate of deflection for the terraces was established (see Figure 9).
Anamnesis

As part of the original scope of work, the structural engineer developed a Historic Structure Report for Fallingwater. The comprehensive study assembled all the available documentation on the structure, including original drawings and calculations by Wright and his structural engineer, Glickman. Furthermore, the HSR included the data collected in the structural assessment which, combined with the historical data, formed a comprehensive picture of the existing state of the structure.

Final Project Objectives

The Initial Project Objectives called for a structural investigation to determine the strength, stiffness, and stability of the terraces of Fallingwater. The result of the investigation indicated that the building was continuing to deflect, and was in danger of collapse (Silman, 2000). Therefore, the trustees of the Western Pennsylvania Conservancy contracted Silman & Associates to develop an intervention plan to stabilize the structure. This included a temporary shoring plan as well as a plan to correct the existing deflections and prevent further deflections.

Figure 9. Deflection over time, Master Terrace at Fallingwater (Silman & Assoc, 1996)
**PROJECT BUDGET**

Including the initial structural investigation, the temporary shoring plan, the permanent structural design, and construction, the five-year renovation of Fallingwater cost nearly $11.5 million (Kamin, 2002).

**STRUCTURAL INTERVENTION**

**Structural Intervention Plan**

The temporary shoring required stabilization of the 1st floor terrace and the streambed below. The structural analysis indicated that three of the four terraces were under reinforced. Given the Final Project Objectives, a structural stabilization would not fulfill all the requirements. In order to not only stop further deflection, but to also counter the existing deflections, a structural consolidation was required. Any structural design needed to be unobtrusive, as the elements in need of intervention were the very elements that make Fallingwater historically and architecturally significant.

**Structural Intervention Design**

The temporary shoring to support the 1st floor terrace and the streambed ledge consisted of “a relatively unobtrusive line of steel columns and girders rising from the streambed of Bear Run to the underside of the first floor. In addition they also shored a portion of the streambed itself, the jutting sandstone ledge over which Bear Run cascades. The ledge was braced with pipe struts in a cave behind the waterfall.” (Silman, 2000).

The Final Project Objectives called for a permanent means of stabilizing the terraces, as well as counteracting the existing deflections. Silman determined that the only practical method of stabilizing the structure without damaging the property’s historic integrity was to post-tension the beams (Silman, 2000). This involved externally attaching concrete blocks to both side of the south (free) ends of the cantilever beams below the first floor terrace. Through those blocks post-tensioning cables were run along the beams, through the east-west running joists, and anchoring into concrete blocks at the north (anchored) ends of the beams. When the intervention was complete, the shoring
was removed and the living room floor replaced. The terraces still sag a bit, as their failure was an important part of the structure’s history (Silman, 2000).

LESSONS LEARNED
Fallingwater is an excellent example of a quality structural intervention. The systematic assessment of the property led to a design that stabilized the structure while keeping the historic fabric intact.

Clearly, the structural engineer was the prime consultant for this project, and therefore part of the intervention design team. Silman Associates is one of the most prestigious conservation engineering firms in the country, providing “qualified” professionals. The conservancy hired the firm for an initial investigation, then established a final scope of work based on this assessment, illustrating the inclusion of materials testing and structural analysis in the budget. Use of NDT techniques provided accurate results and gave vital information about the capacity of the existing structure. The advanced structural analysis was not only performed, but was held in a series of checks and balances to assure that the results were verifiable. An HSR was created to include all the historic research, as well as the structural assessment. The structural design utilized the capacity of the existing structure, and used a non-invasive system to achieve structural stability.
CHAPTER 7
CONCLUSIONS AND LESSONS LEARNED

CONCLUSIONS
The objective of this thesis was to establish a set of criteria by which to measure quality and a set of methods for controlling this quality in the Pre-Construction Phase of structural interventions on historic properties. The Standards of Quality of chapter 3 are based on accepted intervention philosophies and practices, and provide a set of criteria by which to measure quality. Utilizing information gathered in the literature review of Chapter 2, and designed to respond to the Standards of Quality in Chapter 3, the Quality Control Recommendations of Chapter 4 deliver a set of methods for controlling quality.

This thesis has clearly established that the quality of the Pre-Construction Phase sets the stage for the rest of an intervention. Specifically, it has been shown that the quality of the structural intervention design can be directly linked with the quality of the previous steps of the Pre-Construction Phase. Therefore, the inter-related nature of the Standards of Quality and Quality Control Recommendations presented in Chapters 3 and 4 provide a rational approach to establishing quality in a structural intervention.

Furthermore, these Standards and Recommendations provide a logical means of assessing a structural intervention. This is best evidenced in the case studies of chapters 5 and 6. These two case studies differed in the scale and scope of the structural work required in the intervention. Yet, they could be compared because they were analyzed based on a set of Standards of Quality that apply to all structural interventions.

The Quality Control Recommendations provide a systematic means of controlling quality throughout the Pre-Construction Phase. Stating that an intervention was a failure or a success is uninformative and unproductive. To establish the lessons learned from an intervention, it must be shown where and why an intervention succeeded or failed. The Quality Control Recommendations supply this information, clearly linking quality methods with quality results.
LESSONS LEARNED

The subject of quality control within historic interventions is one that holds potential for further research. Specifically, research is needed on the affect on the quality of the intervention of communication between intervention team members and with officials. This would provide valuable insight into the relationship between the control of information and the control of quality on an intervention. Additional research is also needed in the specific field of structural interventions, which might yield some standard design techniques for managing common structural instabilities in historic interventions. By continuing to focus on quality control in structural interventions of historic properties, more will be learned about each of the individual aspects that comprise an intervention, and the effect they have on the intervention as a whole.
REFERENCES


27. Isle of Wight, 2002. freepages.history.rootsweb.com/~iwhistory/boykins.htm. Isle of Wight County Historical Society, Isle of Wight, VA.