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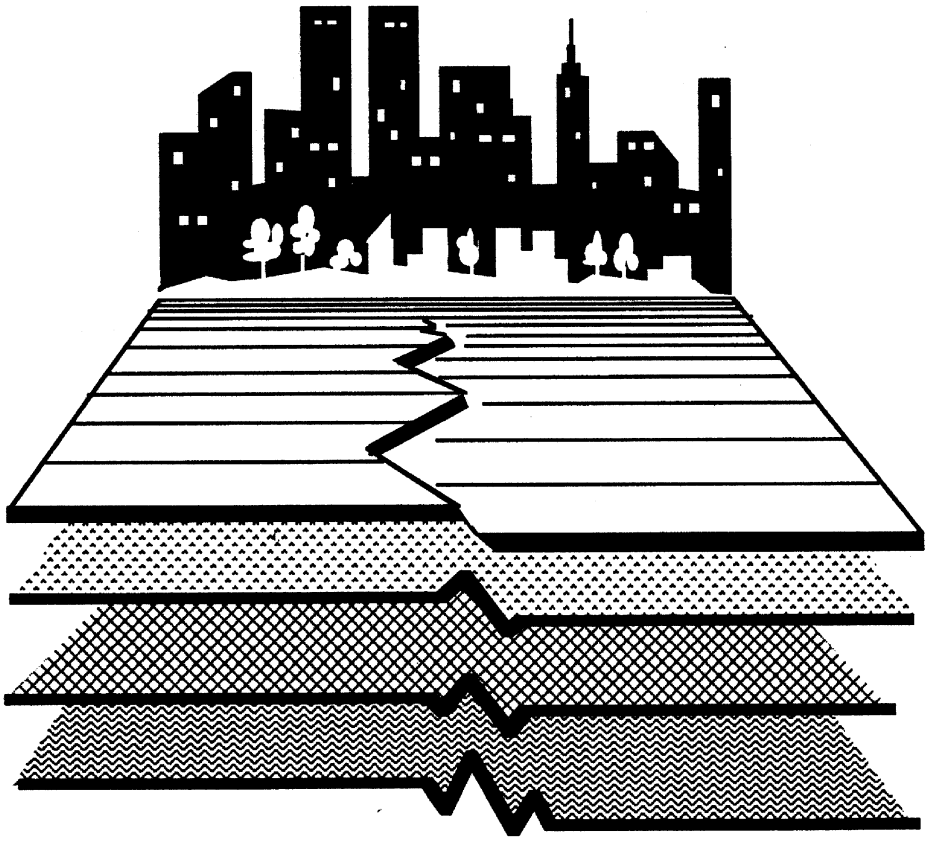

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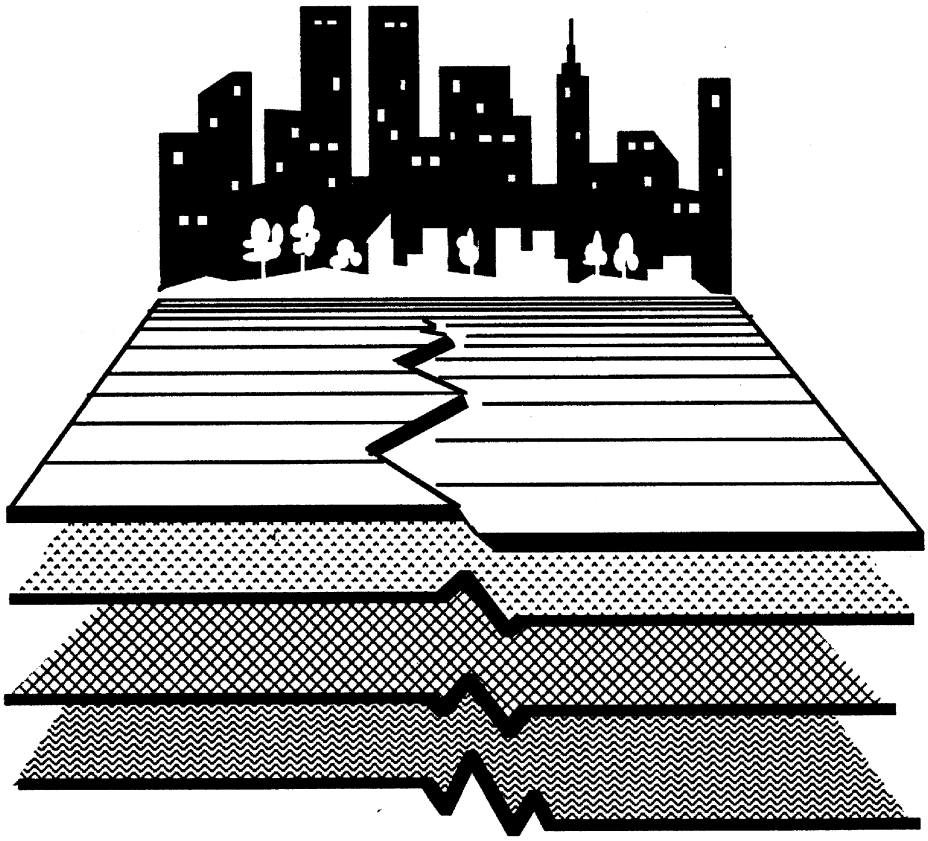

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ASCE American Society of Civil Engineers

GLOBAL TOPICS REPORT ON THE PRESTANDARD AND COMMENTARY FOR THE SEISMIC REHABILITATION OF BUILDINGS

Prepared by
AMERICAN SOCIETY OF CIVIL ENGINEERS
Reston, Virginia

Prepared for
FEDERAL EMERGENCY MANAGEMENT AGENCY
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ASCE Standards Program and the Structural Engineering Institute

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Participants

Project Managers
Ugo Morelli, FEMA Project Officer
Thomas R. McLane, ASCE Project Manager

Project Team
Chris D. Poland, Principal Investigator
Jon A. Heintz, Author
Ashvin Shah, Author
Vicky Vance May, Author
Melvyn Green
Ronald O. Hamburger
William T. Holmes
Jack P. Moehle
Mike Mehrain
Lawrence D. Reaveley
Christopher Rojahn
Jim Rossberg
Daniel Shapiro
Diana Todd

Project Advisory Committee
John R. Baals, Chair
James Cagley
Edwin T. Dean
S.K. Ghosh
James O. Jirsa
Patrick J. Lama
Michael Valley
Richard A. Vognild
Eugene Zeller

Special Study Participants
Daniel P. Abrams
John M. Coil
Craig D. Comartin
W. Paul Grant
Darrick B. Hom
John Hooper
Brian Kehoe
Peter Somers

Desktop Publishing
Kris Ingle

Foreword

Among the FEMA documents covering the topic of making existing buildings more resistant to the effects of earthquakes, this volume occupies a unique position: it is the only one that fulfills a historical need. When the decision was made to convert the performance-based *Guidelines for the Seismic Rehabilitation of Buildings*, FEMA 273, into a prestandard containing mandatory language (FEMA 356), there was considerable concern among design professionals that some of the major characteristics and salient features of the original document (or indeed its very fabric) would be adversely affected in the conversion process. This volume was purposely conceived to allay such concerns by providing a transparent and permanent record of the changes that were made and the reasons for such changes, as well as the major challenges encountered in the conversion process and how they were resolved. It is hoped that this volume will also serve as a useful tool in facilitating the further conversion of the prestandard into an ANSI-approved standard by the American Society of Civil Engineers.

FEMA and the FEMA Project Officer are warmly thankful to the Project Team and consultants, the Project Advisory Committee, and the staff of the American Society of Civil Engineers for their dedicated efforts in completing this unique volume.

The Federal Emergency Management Agency

Preface

This Global Topics Report is the third in a series of reports chronicling the development of the FEMA 273 *NEHRP Guidelines for the Seismic Rehabilitation of Buildings* into the FEMA 356 *Prestandard and Commentary for the Seismic Rehabilitation of Buildings*. The purpose of this report is to provide a narrative discussion and permanent record of the technical changes made to *Guidelines* as the document evolved into the *Prestandard*. It is the vehicle by which new technical information was introduced into the *Prestandard*, as issues were identified and, when possible, resolved by the Prestandard Project Team. For completeness, this report also includes a brief discussion of new concepts introduced to the engineering profession in the publication of the original FEMA 273 *Guidelines* and FEMA 274 *Commentary* documents.

As the *Guidelines* were used by the industry, questions arose regarding application of certain procedures, interpretation of some provisions, and results stemming from portions of the methodology. These questions have been formulated into statements, termed global issues, and recorded in this report for reference during the prestandard project and future revisions of the document.

At the time the *Guidelines* were published, it was known that additional research was needed to refine the accuracy and applicability of certain procedures, and analytical studies were required to test and substantiate certain new concepts and philosophical themes. Unresolved issues, reported by BSSC to be present at the time of publication, are incorporated into this report and identified with the designation 'previously unresolved' in the classification of the issue.

The purpose of Global Topics Report 1, Identification of Global Issues, dated April 12, 1999, was to formulate a statement and classify global issues that had been identified as of the date of the report. The issues identified in that report were presented and discussed at the ASCE Standards Committee Meeting on March 3, 1999, in San Francisco. The discussions resulted in clarifications to some of the issues, as well as a consensus on the recommended classification of each issue. Comments from Standards Committee members were incorporated into the report, and were used by the Project Team in moving issues toward resolution.

Global Topics Report 2 was published on March 22, 2000. The purpose of the second report was to formulate statements for new global issues identified since Global Topics Report 1, and to document resolution of issues that were incorporated into the Second Draft of the Prestandard.

This third and final Global Topics Report contains new global issues identified since the publication of the previous two reports, and final resolutions of previously identified issues. The appendices to this report contain the results of special focused studies, which serve as back-up data to the resolution of selected issues. These studies are referenced in the body of this report, where applicable, and included in the appendices for future reference.

Upon completion of the Case Studies Project, the final report FEMA 343 *Case Studies: An Assessment of the NEHRP Guidelines for the Seismic Rehabilitation of Buildings* was made available to the Prestandard Project Team. Issues identified in FEMA 343 have been incorporated as global issues in this report, and a cross-reference to these issues is contained in Appendix C.

In April, 2000, a *Prestandard* draft document was distributed to the ASCE Standards Committee on the Seismic Rehabilitation of Buildings in an unofficial letter ballot. Ballot comments were reviewed and considered by the Project Team, and changes, were incorporated into the Prestandard. The results of that balloting are documented in the *Ballot Comment Resolution Report on the Unofficial Letter Ballot on the Second Draft of FEMA 356 Prestandard for the Seismic Rehabilitation of Existing Buildings*, included in Appendix L of this report.

This report is organized based on the chapter numbering and sequence of information contained in the original *Guidelines*. New section numbers are referenced for information that was relocated during the development of the *Prestandard*. Included in the body of this report are global technical or editorial issues that merited expanded discussion. Each issue was classified as one or more of the following:

Technical Revision — Issue requiring a revision or clarification of the technical content of the Prestandard

Editorial Revision — Issue requiring a revision or clarification of the technical verbiage of the Prestandard that does not substantially change the technical content.

Commentary Revision — Issue requiring a revision, clarification or expanded discussion in the Commentary

FEMA 343 Case study Consensus Revision — Issue resolved with the help of information gained from the FEMA 343 Case Study Project

Application of Published Research — Issue for which additional research has been published and can be used to supplement the *Prestandard*

Recommended for Basic Research — Issue that requires more information and further detailed study before a resolution can be reached.

Non-persuasive — Issue that was reviewed by the Project Team and the resolution resulted in no change to the *Prestandard*.

Once classified, issues were presented to the Project Team for resolution. Issues that were successfully resolved with the consensus of the Project Team were then incorporated into the *Prestandard* document. Resolved or not, the history of each issue that was identified over the course of the prestandard project is recorded in this report for future reference. Appendix B contains a summary of unresolved issues recommended for future research. It is the hope of the Prestandard Project Team that this Global Topics Report will serve as a resource and a reference for improvements to the FEMA 356 *Prestandard and Commentary for the Seismic Rehabilitation of Buildings* as the document is developed into a standard and incorporated into the practice of seismic rehabilitation.

Table of Contents

Foreword

Preface

1. Introduction 1-1

1.1 New Concepts 1-1

1.2 Global Issues 1-1

1-1 Reorganization of Chapters 1 and 2 1-1

2. General Requirements 2-1

2.1 New Concepts 2-1

2.2 Global Issues 2-2

2-1 Overturning Appears Overly Conservative 2-2
2-2 Ground Motion Pulses Not Covered 2-3
2-3 MCE Exceeds Probabilistic Values 2-4
2-4 Minimum Safety Level Not Specified 2-6
2-5 BSO Should Use Collapse Prevention 2-6
2-6 Baseline Adjustments to Acceptance Criteria Needed 2-7
2-7 Software Not Commercially Available 2-7
2-8 Force-Based Anchorage Criteria Not Consistent 2-7
2-9 Application Based on Rehabilitated Condition 2-8
2-10 No Public Input or Consensus on Acceptable Risk 2-8
2-11 Statistical Basis of Ground Motion Not Stated 2-9
2-12 Vertical Drop in Component Curve 2-9
2-13 Equation for Mean Return Period Specific to 50 Years 2-9
2-14 Performance Levels Imply a Guarantee 2-10
2-15 Inconsistency in Response Spectrum Nomenclature 2-10
2-16 Inconsistency in Definition of Design Earthquake 2-11
2-17 Incorrect Adjustment for Damping at T=0 2-11
2-18 Knowledge Factor Requirements Unclear 2-12
2-19 Upper Limit on DCRs for LSP Needed 2-12
2-20 General Design Requirements Keyed to BSO 2-13
2-21 Building Separation Requirements Too Severe 2-13
2-22 Revise Default Site Class from E to D 2-14
2-23 R_{OT} Needed for IO Performance 2-14
2-24 LS Performance Level Should be Clarified or Eliminated 2-14
2-25 The 2/3 Factor Estimating Vertical Seismic Forces is Not Accurate 2-15
2-26 Additional Guidance on Damping Needed 2-15
2-27 Application of Site Coefficients Not Consistent with the IBC 2-15
2-28 Equation for Building Separation is Overconservative 2-16

3. Modeling and Analysis ____ 3-1

3.1 New Concepts ____ 3-1

3.2 Global Issues ____ 3-2

3-1 Ct=0.06 for Wood Buildings Not Documented ____ 3-2
3-2 Application of Method 3 Period Calculation Not Clear ____ 3-2
3-3 Empirical Formulas Underestimate Period ____ 3-2
3-4 Multidirectional Effects Need Clarification ____ 3-3
3-5 Mass Participation Effects Not Considered ____ 3-3
3-6 NSP Uniform Load Pattern Overly Conservative ____ 3-4
3-7 Reconcile FEMA 273 and 310 ____ 3-4
3-8 URM Special Procedure Not Included ____ 3-5
3-9 Reconcile FEMA 273 and Other Procedures ____ 3-5
3-10 Upper Limit on Pseudo Lateral Force ____ 3-6
3-11 Clarify Primary, Secondary, Force-, and Deformation-Controlled ____ 3-6
3-12 Reference to Alternative NSP Procedures Needed ____ 3-6
3-13 LSP and NSP Results Need Calibration ____ 3-7
3-14 Reliability Information Not Provided ____ 3-7
3-15 LSP Should be a Displacement Calculation ____ 3-7
3-16 Combined with 2-2, 3-5, 3-6 ____ 3-8
3-17 C1 Factor Overly Conservative ____ 3-8
3-18 Duration Effects Not Considered ____ 3-8
3-19 Marginal Gravity Load Capacity Not Considered ____ 3-8
3-20 Inelastic Cyclic Properties Needed ____ 3-9
3-21 Combined with 3-10 ____ 3-9
3-22 Amplification of Torsion Needs Clarification ____ 3-9
3-23 Substantiation of C1, C2, C3 Needed ____ 3-9
3-24 Reorganization of Sections 3.2 and 2.11 ____ 3-10
3-25 Definition of Pushover Curve Not Complete ____ 3-10
3-26 Application of the *J*-factor Not Clear ____ 3-11
3-27 Degradation Effects Double Counted in LSP ____ 3-12
3-28 Global Acceptance Criteria Needed ____ 3-12
3-29 Snow Load Should be Specified ____ 3-13
3-30 Application of η-factor is Overconservative ____ 3-13
3-31 Consider Reduced Demands Due to Actual Torsion ____ 3-14
3-32 No Maximum Limit on Method 1 Period ____ 3-14
3-33 Omit C2 Factor For Nonlinear Procedures ____ 3-15
3-34 Alternate Empirical Period Calculation for Flexible Diaphragms ____ 3-15
3-35 Omit C_1 C_2 C_3 Factors from the Denominator of Diaphragm F_p ____ 3-16
3-36 Application of the NSP With Non-Rigid Diaphragms Needs Revision ____ 3-16
3-37 C_0 Factors Overconservative for Uniform Load Pattern ____ 3-17
3-38 Procedures for Torsional Amplification are Unconservative ____ 3-17

4. Foundation and Geotechnical Hazards ____ 4-1

4.1 New Concepts ____ 4-1

4.2 Global Issues ____ 4-1

4-1 Spring Limitations Required in NSP ____ 4-1
4-2 Spring Procedure Not Applicable to Strip Footings ____ 4-2
4-3 Lateral Soil Spring Procedure Needs Refinement ____ 4-2
4-4 Nonlinear Soil Spring Information Needed ____ 4-3
4-5 Shear Modulus Factors Inconsistent with NEHRP ____ 4-3
4-6 Soil Parametric Range Appears Extreme ____ 4-3
4-7 Classification of Foundation Rigidity ____ 4-4
4-8 Guidance for Rocking Needed ____ 4-4
4-9 Presumptive Values for Piles Missing ____ 4-4

5. Steel and Cast Iron ____ 5-1

5.1 New Concepts ____ 5-1

5.2 Global Issues ____ 5-1

5-1 *m*-factors Appear Overly Conservative ____ 5-1
5-2 Steel Default Values Too Low ____ 5-2
5-3 Insufficient Limits for Cast Iron ____ 5-2
5-4 Too Much Testing is Required ____ 5-3
5-5 Presentation by System Type is Redundant ____ 5-3
5-6 Aluminum is Not Included ____ 5-4
5-7 Infill Evaluation Criteria Not Complete ____ 5-4
5-8 Inconsistent Specification of Acceptance Criteria ____ 5-4
5-9 *m*-factors Less Than 1.0 Too Low ____ 5-5
5-10 Chapter 5 Acceptance Criteria Inconsistent and Unclear ____ 5-5
5-11 Guidance on calculation of strength of anchor bolts needed ____ 5-6
5-12 Braced Frame Connection Requirements Need Clarification ____ 5-6
5-13 Incorporate SAC Research Into Chapter 5 ____ 5-7
5-14 Steel Acceptance Criteria is Based on Component Length ____ 5-7
5-15 The Ratio Between IO and LS Acceptance Criteria Appears Too Large ____ 5-7
5-16 Nonlinearity is Permitted in Column Base Plates ____ 5-8
5-17 Tension-only Braces Have Full Nonlinear Deformation Limits ____ 5-8

6. Concrete **6-1**
6.1 New Concepts 6-1
6.2 Global Issues 6-2
6-1 *m*-factors Appear Overly Conservative 6-2
6-2 Presentation by System Type is Redundant 6-2
6-3 Too Much Testing is Required 6-3
6-4 Guidance for Concrete Infill Panels Needed 6-3
6-5 Inconsistent Definition of Weak Story 6-4
6-6 Clarify Shear Wall Component Definitions 6-4
6-7 *m*-factors Less Than 1.0 Too Low 6-4
6-8 Tables 6-13 and 6-14 Reversed 6-5
6-9 *m*-factors Less Than 2.0 Worse Than Force-Controlled 6-5
6-10 Column Acceptance Criteria Overly Conservative 6-5
6-11 Footnote 1, Table 6-20 Incorrect 6-6
6-12 Table 6-17 Missing Headings 6-6
6-13 Column P-M Interaction Unclear 6-6
6-14 Guidance for Lightweight Concrete Needed 6-7
6-15 Guidance for Square Rebar Needed 6-7
6-16 *m*-factors for Concrete Diaphragms Needed 6-7
6-17 Acceptability for Columns in Tension Missing 6-8
6-18 Calculation of M_y for Shearwalls Unconservative 6-8
6-19 Omit Sampling of Prestressing Steel 6-8
6-20 Concrete Flange Provisions Unconservative 6-8
6-21 Clarify Definition of Closed Stirrups, Ties and Hoops 6-9

7. Masonry **7-1**
7.1 New Concepts 7-1
7.2 Global Issues 7-2
7-1 *m*-factors Appear Overly Conservative 7-2
7-2 URM h/t Limits Independent of Performance Level 7-2
7-3 Interpolation Not Specified 7-2
7-4 Guidance for Infill Panels with Openings Needed 7-3
7-5 Quantitative Definition of Masonry Terms Needed 7-3
7-6 1.25 fy Not Specified for Masonry 7-4
7-7 h/t Ratios for S_{X1} Exceeding 0.5g Needed 7-4
7-8 Clarify Application of Equations 7-5 and 7-6 7-4
7-9 Clarify Definition of Effective Height 7-5
7-10 Masonry Shear Strength Based on Average Test Values is Unconservative 7-5
7-11 URM Shear Strength Should be Force-Controlled 7-5

8. Wood and Light Metal Framing 8-1
8.1 New Concepts 8-1
8.2 Global Issues 8-1
8-1 *m*-factors Appear Overly Conservative 8-1
8-2 Guidance for Diaphragm Chord Area Needed 8-2
8-3 Wood Values Based on Judgment 8-2
8-4 Anomalous *m*-factors for Different Assemblies 8-2
8-5 Combined with 3-8 8-2
8-6 Use of Default Values Needs Clarification 8-3
8-7 Inconsistent Requirements for Connections 8-3
8-8 Guidance on Wood Components in Compression Needed 8-3
8-9 Lower-Bound Capacities for Wood Components Needed 8-4
8-10 Stiffness Values for Wood Assemblies are Not Supported by Tests 8-4
8-11 Wood Conversion Factors are not Supported by Tests 8-5
9. Seismic Isolation and Energy Dissipation 9-1
9.1 New Concepts 9-1
9.2 Global Issues 9-1
9-1 Procedures Require Validation 9-1
9-2 Inconsistent Nomenclature 9-1
9-3 Clarify Use of C1, C2, C3 with Isolation 9-2
9-4 Chapter 9 Needs Controls for Proper Application 9-2
10. Simplified Rehabilitation 10-1
10.1 New Concepts 10-1
10.2 Global Issues 10-1
10-1 FEMA 310 as Basis for Chapter 10 10-1
10-2 Simplified Rehabilitation Equivalent to BSO 10-2
10-3 Chapter 10 Too Complex to be Simplified Rehabilitation 10-2
10-4 Reconcile Differences Between FEMA 310 and FEMA 356 10-3
11. Architectural, Mechanical, and Electrical Components 11-1
11.1 New Concepts 11-1
11.2 Global Issues 11-1
11-1 Preservation of Egress Not Required 11-1
11-2 Extent of Nonstructural Investigation Unclear 11-2
11-3 Vertical Acceleration Criteria Missing 11-2
11-4 Effects of Nonstructural on Structural Response 11-2
11-5 Sensitivity of Nonstructural to Deformation 11-3
11-6 Glazing Acceptance Criteria Outdated 11-3
11-7 Acceptance Criteria Needed for Other Performance Levels 11-3
11-8 Equation 11-2 (11-3) Variation with Height 11-4
11-9 Heavy Partitions—Scope and Definition 11-4
11-10 Guidance on Nonstructural Operational Performance Needed 11-4
11-11 Nonstructural IO and LS Criteria need calibration 11-5
11-12 Storage Racks as Non-Building Structures 11-5
11-13 Floating Concrete Isolation Floors are not Addressed 11-5

A. Miscellaneous Issues **A-1**

A.1 Global Issues A-1

A-1 Reference to Other Standards Incomplete A-1
A-2 Quality Assurance Not Specified A-1
A-3 Permissive Language Not Standard Compatible A-1
A-4 Triggers for Seismic Rehabilitation Missing A-2
A-5 Drift Limits Omitted A-2
A-6 Behavior of Rehabilitated Elements A-2
A-7 Expected and Lower Bound Strengths Unclear A-3
A-8 Paragraphs Contain Multiple Provisions A-3
A-9 Rehabilitation Measures as Commentary A-4
A-10 Standard/Commentary Split A-4
A-11 No Acceptance Criteria for Secondary IO A-4
A-12 Acceptance Criteria for Archaic Materials Needed A-5

B. Research and Study Needs ____ B-1

2-1 Overturning Appears Overly Conservative ____ B-1
2-2 Ground Motion Pulses Not Covered ____ B-1
2-6 Baseline Adjustments to Acceptance Criteria Needed ____ B-1
2-7 Software Not Commercially Available ____ B-1
2-10 No Public Input or Consensus on Acceptable Risk ____ B-1
2-19 Upper Limit on DCRs for LSP Needed ____ B-1
2-23 R_{OT} Needed for IO Performance ____ B-1
2-24 LS Performance Level Should be Clarified or Eliminated ____ B-1
2-25 The 2/3 Factor Estimating Vertical Seismic Forces is Not Accurate ____ B-2
2-26 Additional Guidance on Damping Needed ____ B-2
2-28 Equation for Building Separation is Overconservative ____ B-2
3-1 Ct=0.06 for Wood Buildings Not Documented ____ B-2
3-4 Multidirectional Effects Need Clarification ____ B-2
3-6 NSP Uniform Load Pattern Overly Conservative ____ B-2
3-10 Upper Limit on Pseudo Lateral Force ____ B-2
3-13 LSP and NSP Results Need Calibration ____ B-2
3-14 Reliability Information Not Provided ____ B-2
3-15 LSP Should be a Displacement Calculation ____ B-2
3-17 C1 Factor Overly Conservative ____ B-2
3-18 Duration Effects Not Considered ____ B-3
3-19 Marginal Gravity Load Capacity Not Considered ____ B-3
3-20 Inelastic Cyclic Properties Needed ____ B-3
3-23 Substantiation of C1, C2, C3 Needed ____ B-3
3-30 Application of η-factor is Overconservative ____ B-3
3-34 Alternate Empirical Period Calculation for Flexible Diaphragms ____ B-3
3-36 Application of the NSP With Non-Rigid Diaphragms Needs Revision ____ B-3
3-38 Procedures for Torsional Amplification are Unconservative ____ B-3
4-3 Lateral Soil Spring Procedure Needs Refinement ____ B-3
4-4 Nonlinear Soil Spring Information Needed ____ B-3
5-1 *m*-factors Appear Overly Conservative ____ B-4
5-14 Steel Acceptance Criteria is Based on Component Length ____ B-4
5-15 The Ratio Between IO and LS Acceptance Criteria Appears Too Large ____ B-4
5-16 Nonlinearity is Permitted in Column Base Plates ____ B-4
6-1 *m*-factors Appear Overly Conservative ____ B-4
6-17 Acceptability for Columns in Tension Missing ____ B-4
6-18 Calculation of M_y for Shearwalls Unconservative ____ B-4
6-20 Concrete Flange Provisions Unconservative ____ B-4
7-1 *m*-factors Appear Overly Conservative ____ B-4
7-4 Guidance for Infill Panels with Openings Needed ____ B-4
7-10 Masonry Shear Strength Based on Average Test Values is Unconservative ____ B-5
7-11 URM Shear Strength Should be Force-Controlled ____ B-5
8-1 *m*-factors Appear Overly Conservative ____ B-5
9-1 Procedures Require Validation ____ B-5
9-4 Chapter 9 Needs Controls for Proper Application ____ B-5
11-4 Effects of Nonstructural on Structural Response ____ B-5
11-5 Sensitivity of Nonstructural to Deformation ____ B-5
11-8 Equation 11-2 (11-3) Variation with Height ____ B-5

11-10 Guidance on Nonstructural Operational Performance Needed B-5
11-11 Nonstructural IO and LS Criteria need calibration B-5
11-12 Storage Racks as Non-Building Structures B-5
11-13 Floating Concrete Isolation Floors are not Addressed B-6
A-6 Behavior of Rehabilitated Elements B-6
A-12 Acceptance Criteria for Archaic Materials Needed B-6

C. Special Study 1—
Early Input from the BSSC Case Studies Project **C-1**

D. Special Study 2—
Analysis of Special Procedure Issues **D-1**

E. Special Study 3—
Improvements to the FEMA 273 Linear Static Procedure **E-1**

F. Special Study 4—
Foundation Issues **F-1**

G. Special Study 5—
Report on Multidirectional Effects and P-M Interaction on Columns **G-1**

H. Special Study 6—
Acceptability Criteria (Anomalous *m*-values) **H-1**

I. Special Study 7—
Report on Study of C-Coefficients **I-1**

J. Special Study 8—
Incorporation of Selected Portions of Recent Related Documents **J-1**

K. Special Study 9—
Incorporating Results of the SAC Joint Venture
Steel Moment Frame Project **K-1**

L. Ballot Comment Resolution Report **L-1**

M. Minority Opinion Report **M-1**

N. Special Study 10—
Issues Related to Chapter 7 **N-1**

O. Special Study 11—
Wood Issues **O-1**

P. Special Study 12—
FEMA 310 and FEMA 356 Differences **P-1**

Q. Special Study 13—
Study of Nonstructural Provisions **Q-1**

1. Introduction

Chapter 1 provides an introduction to the *Guidelines*. It describes how the document relates to other documents and explains how it is to be used in a seismic rehabilitation program. It also provides an overview of significant new features (concepts) that are introduced in the following chapters.

1.1 New Concepts

Chapter 1 provides a brief discussion of major new concepts introduced in the *Guidelines*. These concepts are listed below for information only, and discussed in greater detail in the following chapters.

- Seismic performance levels and rehabilitation objectives.
- Simplified and systematic rehabilitation methods.
- Varying methods of analysis.
- Quantitative specifications of component behavior.
- Procedures for incorporating new information and technologies into rehabilitation.

1.2 Global Issues

1-1 **Reorganization of Chapters 1 and 2**

Overlap and redundancy between Chapters 1 and 2 of the *Guidelines* makes it difficult to find and apply all provisions applicable to a given rehabilitation project.

Section: Chapter 1, all; Chapter 2, all.

Classification: *Editorial Revision.*

Discussion: None.

Resolution: Information contained in these chapters has been combined and reorganized so that Prestandard Chapter 1 now contains all information related to an overview of the rehabilitation process including the definition and selection of rehabilitation objectives, performance levels, and seismic hazard. Prestandard Chapter 2 now contains all general information related to applying the rehabilitation methodology. All non-mandatory information related to use of the standard for local or directed risk mitigation programs has been split out into Prestandard Appendix A.

2. General Requirements

(Simplified and Systematic Rehabilitation)

Chapter 2 describes the overall framework of the methodology. It describes performance levels rehabilitation options and how rehabilitation objectives are set. It discusses the basis of the seismic hazard determination and the component acceptance criteria. It sets general limitations on the application of the various analysis procedures and describes general analysis requirements.

2.1 New Concepts

- Rehabilitation using new and existing components: The procedures for simplified and systematic rehabilitation utilize existing elements to their fullest capacity. Basic, enhanced, partial and reduced rehabilitation objectives are defined that allow for the selection of a range of rehabilitation strategies using existing components to varying degrees.
- Displacement-based design: The analysis methodology uses a displacement-based philosophy that evaluates the behavior of individual components of the building at the maximum expected displacements of the structure. This philosophy was adopted as being more indicative of actual member performance than traditional force-based analysis procedures. In the linear procedures of the methodology, displacement-based concepts are translated back to force-based calculations to facilitate application by using procedures that are more familiar to engineers.
- Performance levels and rehabilitation objectives: Building performance is characterized by the performance of structural and nonstructural elements. Performance levels are related to certain limiting damage states of structural and nonstructural elements. A rehabilitation objective is a statement of the desired building performance level when subjected to the selected earthquake hazard level, and must be selected in order to use the methodology.
- Primary and secondary elements: Primary elements provide the overall resistance of the structure against collapse, and must not be damaged beyond usable limits. Secondary elements are those elements for which damage does not compromise the integrity of the structure, and higher levels of damage can be permitted. The concept of primary and secondary elements was introduced to take advantage of the inherent redundancy in some structures by allowing a few selected elements to experience excessive damage, and prevent less important elements from controlling the rehabilitation objective.
- Design parameters from physical tests: Destructive and nondestructive testing is required by the methodology in order to determine physical parameters in sufficient detail to reliably evaluate component strengths. A reliability coefficient, κ, was introduced to reduce calculated strengths considering the quality and uncertainty of information about the existing structure.
- Determination of regular and irregular structures: The regularity or irregularity of a structure affects the applicability of the analysis procedures. If a regular building has relatively limited inelastic demands, linear procedures are sufficiently accurate for evaluation. Regularity is determined by calculation of element Demand to Capacity Ratios (DCRs). Low DCRs are an indication of low inelastic demands. However, if calculated DCRs are high, there is a high potential for a concentration of inelastic activity at an irregularity that may not be accurately reflected in an elastic analysis.

- Hazard parameter determination: The seismic hazard in conjunction with building performance is used to define the rehabilitation objective. The *Guidelines* consider two hazard levels, Basic Safety Earthquake 1 (BSE-1) and Basic Safety Earthquake 2 (BSE-2). These correspond to a 10%/50 year earthquake and 2%/50 year earthquake respectively. In addition to BSE-1 and BSE-2, rehabilitation objectives may be formed using seismic hazards from earthquakes with any defined probability of exceedance. Procedures are included for determining hazard parameters for these other earthquakes, which can then be used for enhanced or reduced rehabilitation objectives.
- Simplified and Systematic Rehabilitation: Simplified rehabilitation allows for the design of building rehabilitation measures without requiring full building analysis or strengthening. Simplified rehabilitation can only be used in applications of limited rehabilitation. Systematic rehabilitation consisting of a comprehensive evaluation of the entire structural system is required to achieve the Basic Safety Objective of the *Guidelines*.
- The absence of drift control checks or limits: The analysis methodology evaluates the acceptability of elements in their displaced state at maximum expected displacements. Since displacements and their effects are explicitly calculated, drift limits are implicitly evaluated and not included.

2.2 Global Issues

2-1 Overturning Appears Overly Conservative

Overturning calculations at pseudo lateral force levels appear to be overly conservative and can predict overturning stability problems that are not well correlated with observed behavior.

Section: 2.11.4 (new sections 2.6.4 and 3.2.10).

Classification: *Technical and Basic Research (previously unresolved).*

Discussion: Related to issue 2-23 regarding R_{OT} for IO performance. Upon completion of the *Guidelines*, BSSC identified the need to develop improved procedures for evaluating overturning. The *Guidelines* evaluate overturning stability at seismic force levels representing expected building displacements. Thus overturing effects are larger than typically calculated for new buildings using current code-based analytical procedures that reduce earthquake forces by an *R*-factor. In spite of this force reduction, however, code-based design procedures have yielded satisfactory performance with regard to overturning. It, therefore, seems unnecessary to require buildings to remain stable at full pseudo lateral force levels. While the LSP will permit incorporation of foundation flexibility in the analysis, this does not fully resolve the problem. Simplified rocking calculation procedures are available in the literature, but have not yet been incorporated into the prestandard. Nonlinear analytical techniques are currently the best methods available to reconcile the difference between calculated and observed results.

Resolution: Prestandard Sections 2.6.4 and 3.2.10 have been revised to incorporate the overturning sidebar from the *Guidelines* into the Prestandard. The intent of the sidebar was to provide alternative overturning criteria that would be consistent with NEHRP provisions for new buildings. The sidebar overturning equation has been revised to reduce the earthquake force demand, $Q_{E,}$, by C_1, C_2, and C_3, which are displacement amplifiers. Due to the 0.75 factor on demands present in NEHRP, R_{OT} has been revised to 10 and 8 for collapse prevention and life safety respectively to calibrate overturning criteria for consistency with UBC K=1.0 force levels.

2-2 Ground Motion Pulses Not Covered

Ground motion duration and pulses are not explicitly considered in the analysis procedures except for the use of higher acceleration values specified in regions near active faults.

Section: 2.6 (new section 1.6)

Classification: *Recommended for Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to develop procedures for evaluating near field ground motion effects. The results of the NSP, in particular, may be very sensitive to earthquake pulses. Proper consideration of duration and pulses may require a time-history analysis, and records may or may not be available. No guidance on appropriate consideration of these effects is provided.

Resolution: Unresolved pending future research.

2-3 MCE Exceeds Probabilistic Values

In some areas (primarily areas of moderate to high seismicity), there are locations that have mapped acceleration response parameters on MCE maps that exceed the probabilistic response acceleration parameters for the 2%/50 years earthquake hazard.

Section: 2.6, 2.6.1, 2.6.1.1, 2.6.1.2, 2.6.2 (new sections 1.6.1.1, 1.6.1.2, 1.6.2).

Classification: *Commentary Revision.*

Discussion: Related to issue 2-16 regarding the definition of design earthquake. The latest seismic design maps, the Maximum Considered Earthquake (MCE) ground motion maps, were developed by the USGS in conjunction with the Seismic Design Procedure Group appointed by the BSSC. The effort utilized the latest seismological information to develop design response acceleration parameters with the intent of providing a uniform margin against collapse in all areas of the United States. The MCE ground motion maps are based on seismic hazard maps which are (1) 2%/50 years earthquake ground motion hazard maps for regions of the United States which have different ground motion attenuation relationships and (2) deterministic ground motion maps in regions of high seismicity with the appropriate ground motion attenuation relationships for each region. The deterministic maps are used in regions of high seismicity where frequent large earthquakes are known to occur, and the rare earthquake ground motions corresponding to the 2%/50 years hazard are controlled by the large uncertainties in the hazard studies which results in unusually high ground motions. These high ground motions were judged by the Seismic Design Procedures Group to be inappropriate for use in design. The use of these different maps to develop the MCE maps required the Seismic Design Procedure Group to define guidelines for integrating the maps into the design ground motion maps.

The most rigorous guideline developed was for integrating the probabilistic and the deterministic maps. To integrate the probabilistic maps and the deterministic map, a transition zone set at 150% of the level of the 1994 NEHRP Provisions was used and is extensively discussed in the 1997 NEHRP Provisions Commentary. The goal of this guideline was to not exceed the deterministic ground motion in these areas of high seismicity where the earthquake faults and maximum magnitudes are relatively well defined. The remaining guidelines were more subjective, and were related to smoothing irregular contours, joining contours in areas where closely spaced contours of equal values occurred (particularly in areas where faults are known to exist, but the hazard parameters are not well defined), increasing the response acceleration parameters in small areas surrounded by higher parameters, etc.

2-3 (continued) Based on the process used to develop the MCE maps, there are some locations where the mapped acceleration response parameters on the MCE maps exceed the probabilistic 2%/50 years seismic hazard maps. These locations primarily occur in the New Madrid, Missouri area, the Salt Lake City area, coastal California, and in the Seattle, Washington area. The areas where this exceedance occurs are relatively small and the exceedance in general is less than about 10 to 15 percent. The maximum exceedance in very small areas varies from about 30 to 50 percent. The areas where these larger exceedances occur are in areas where there is a large uncertainty in the seismic hazard, and as more information is obtained the likelihood that the 2%/50 years maps increasing is relatively high. In addition, where these larger exceedances occur, the acceleration response parameters are high (short period varies vary from about 1.25g to 1.8g and long period values range from 0.5g to 0.8g for B soil conditions). In these locations, the rehabilitation costs will be high, which makes these locations good candidates for site specific seismic hazard studies and non-linear analyses of the structures. Consideration of the site-specific studies and non-linear analyses should reduce the cost impact of the higher values.

Change in the definition of BSE-2 to consider probabilistic maps in conjunction with the MCE maps is not recommended for the following reasons:

1. The areas where the differences between the MCE maps and the 2%/50 years maps occur are considered to be small.
2. The differences in these areas are generally small and even the larger differences are considered to be well within the uncertainty associated with the maps in these areas.
3. The acceleration response parameters in these areas are generally high values and will result in high rehabilitation cost which should lead to consideration of site specific seismic hazard studies and non-linear analyses in order to minimize the cost.
4. The use of maps other than the MCE maps will result in differences with other codes and standards which will result in confusion and present an unneeded complexity in the design process.
5. A standing subcommittee was formed by BSSC in 1997 to address seismic hazard mapping issues and the subcommittee will continue to evaluate new data and information to ensure the MCE maps reflect the best scientific and engineering knowledge available.

In summary, the MCE maps were developed using a careful process of integrating probabilistic and determinist maps considering uncertainties in available knowledge. The resulting mapped values are an intentional result of this process so the BSE-2 hazard level will continue to be defined from the MCE maps.

Resolution: The commentary of Section 1.6 has been revised to reflect the above discussion.

2-4 Minimum Safety Level Not Specified

The *Guidelines* should specify a minimum safety level, and that level should be set at the Basic Safety Objective (BSO).

Section: 2.4.1 (new section 1.4).

Classification: *Commentary Revision.*

Discussion: The *Guidelines* are intended to permit the selection of the rehabilitation objective that is most appropriate for a given situation. This is a policy issue that should be decided by the local authority having jurisdiction. However, the document must provide sufficient information so that informed decisions can be made.

Resolution: The commentary of Prestandard Section 1.4 has been expanded with additional text from FEMA 274 to provide additional information on selection of rehabilitation objectives.

2-5 BSO Should Use Collapse Prevention

The BSO should be based on the Collapse Prevention Performance Level instead of the Life Safety Performance Level. Consider a single level evaluation approach using BSE-2 at the collapse prevention performance level.

Section: 2.5.1.

Classification: *Non-persuasive.*

Discussion: Collapse prevention implies that the building is on the verge of collapse, but has not yet collapsed. If the building does not collapse, in part or in total, some may consider that the life safety objective has been met. At the 3/3/99 Standards Committee meeting this issue was reclassified as non-persuasive. The Life Safety Performance Level, as defined in the *Guidelines*, includes an intentional margin of safety against collapse for the lower level earthquake. The collapse prevention check at the higher level was intended to safeguard the building against collapse due to a rare earthquake. Neither case governs in all situations. The definition of BSO as a two-level approach was set with this in mind, and use of a single level evaluation at the collapse prevention performance level would substantially change the intent.

Resolution: No change proposed.

2-6 **Baseline Adjustments to Acceptance Criteria Needed**

Use of experimental data to set acceptance criteria has led to some inconsistency in calculated versus expected results. It may be appropriate to consider some baseline adjustments to acceptance parameters.

Section: 2.9.4 (new section 2.4.4), Chapters 5 through 8.

Classification: *Technical Revision and Basic Research.*

Discussion: Baselining adjusts values to make sense. However, just because experimental results are contrary to historically used R-values does not mean the experiments are wrong. Special Study 6 – Acceptability Criteria (Anomalous *m*-values) was funded to research this issue. The study concluded that even non-ductile components have some limited level of inelastic deformation capacity, and that *m*-factors for deformation-controlled actions could be conservatively adjusted to minimum values of 1.25, 1.50 and 1.75 for IO, LS and CP performance levels respectively. This conclusion did not impact *m*-factor tables in Chapters 7 and 8. The results of this study are still under consideration by the Project Team. Changes to *m*-factor tables in Chapters 5 and 6 are on hold pending further discussion.

Resolution: Unresolved pending future research.

2-7 **Software Not Commercially Available**

Nonlinear software capable of performing 3-D nonlinear analyses is not commercially available to the building engineering community. Any building that requires this analysis based on *Guidelines* provisions cannot be rehabilitated to meet the provisions.

Section: 2.9 (new section 2.4).

Classification: *Recommended for Basic Research.*

Discussion: None.

Resolution: Unresolved pending future research.

2-8 **Force-Based Anchorage Criteria Not Consistent**

Wall anchorage and non-structural force-based evaluation criteria are inconsistent with the overall displacement-based methodology.

Section: 2.11.7, 2.11.8 (new sections 2.6.2, 2.6.8), Chapter 11.

Classification: *Non-persuasive.*

Discussion: Force-based evaluation criteria use force amplification factors to increase reliability. This procedure is not based on an evaluation of displacements or deformations. Similarly, this issue would apply to any force-based evaluation procedure in the *Guidelines*. At the 3/3/99 Standards Committee meeting this issue was reclassified as non-persuasive. Force-based procedures are not inconsistent with the methodology. Wall anchors are treated as force-controlled elements with a defined force level.

Resolution: No change proposed.

2-9 Application Based on Rehabilitated Condition

It is not clear that the limitations in the application of linear versus nonlinear procedures or static versus dynamic procedures apply to the condition of the rehabilitated building.

Section: 2.9 (new section 2.4).

Classification: *Technical Revision.*

Discussion: The applicability of analysis procedures depends on the condition of the structure that is being analyzed. If the structure is being rehabilitated, the configuration of the rehabilitated structure is important. If the analysis is intended to justify that no rehabilitation is required, then the configuration of the existing structure is important.

Resolution: Prestandard Section 2.4 has been revised to clearly state that the configuration of the rehabilitated structure determines whether the structure is classified as irregular or not.

2-10 No Public Input or Consensus on Acceptable Risk

The present definitions of performance levels and acceptable risk have been developed by engineers with little input from the public, and may not be consistent with popular notions.

Section: 2.5 (new section 1.5).

Classification: *Commentary Revision and Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to develop a popular consensus on performance levels and acceptable risk.

Resolution: The commentary of Prestandard Section 1.5 has been expanded to provide additional clarification on the definition of performance levels. Prestandard commentary tables C1-3 through C1-7 provide detailed descriptors of damage. Further resolution of this issue is recommended for future research.

2-11 Statistical Basis of Ground Motion Not Stated

The statistical basis of ground motion hazards is not explicitly stated in the *Guidelines*. This information is needed to properly develop site specific hazard information.

Section: 2.6.2.1 (new section 1.6.2.1).

Classification: *Technical Revision.*

Discussion: It is unclear if ground motion hazards are to be expressed using mean spectra, median spectra, mean plus one standard deviation or some other statistical basis. The *Guidelines* are silent on how to develop BSE-1 and BSE-2 parameters when using site-specific hazard information.

Resolution: New prestandard Sections 1.6.2.1.3, 1.6.2.1.5, and 1.6.2.1.6 were developed to specify the statistical basis of site-specific hazard information. The BSE-1 hazard corresponds to mean spectra at the 10%/50 year probability of exceedance. Probabilistic BSE-2 hazard corresponds to mean spectra at the 2%/50 year probability of exceedance. Deterministic BSE-2 hazard corresponds to 150% of the median spectra for the characteristic event.

2-12 Vertical Drop in Component Curve

The vertical drop in the idealized component load versus deformation curve is computationally difficult and leads to computer convergence problems.

Section: 2.9.4, 5.4.2.2.B, 6.4.1.2.B, 7.4.2.3.B, 8.4.4.3, (new sections 2.4.4, 5.5.2.2.2, 6.4.1.2.2, 7.4.2.3.2).

Classification: *Technical Revision.*

Discussion: The idealized force versus deformation backbone curves show a vertical drop when components reach their deformation capacity limits at collapse prevention (point C to point D). Point D is not related to any particular level of deformation and is not keyed to any acceptance criteria. This vertical drop is an unnecessary simplification that leads to computational difficulties.

Resolution: Prestandard figures C2-1, 5-1, 6-1, 7-1 and 8-1 have been revised to show a slight slope from point C to Point D. The commentary in Section 2.4.4 has been expanded to discuss the reason for the slope.

2-13 Equation for Mean Return Period Specific to 50 Years

Equation 2-2, calculating the mean return period at the desired probability of exceedance, is more complex than necessary and is only specific to recurrence intervals of 50 years.

Section: 2.6.1.3 (new section 1.6.1.3, Eq 1-2).

Classification: *Technical Revision.*

Discussion: A more general equation can be used that is simpler, technically correct and can be used for recurrence intervals other than 50 years.

Resolution: Prestandard Equation 1-2 has been revised to the more general form $P_R = -T/\ln(1-P_E)$, where P_R is the mean return period and P_E is the probability of exceedance in time T.

2-14 Performance Levels Imply a Guarantee

The detailed specification of performance levels may imply a "guarantee" of building performance in an earthquake, and increase liability of engineers.

Section: 2.5 (new sections 1.2.2 and 1.5).

Classification: *Editorial and Commentary Revision.*

Discussion: Building owners, and the public, may interpret designing to specific performance levels as implying a guarantee that selected performance will be achieved. Some have expressed concern over this notion while others feel it is no different than the current situation in which designing to current code is expected to provide life safe performance. It does not result in any more liability than is already implicit in the practice of design professionals.

Resolution: The commentary of Prestandard Sections 1.2.2 and 1.5 have been expanded to clarify that an uncertainty exists in predicting damage states and emphasize that there is still a possibility for damage in excess of the predicted damage state to occur in some cases. The word "Target" has been added to the designation of Building Performance Levels in the prestandard to imply the notion that the selected performance level is a goal and not a certainty.

2-15 Inconsistency in Response Spectrum Nomenclature

The response spectrum nomenclature used in the *Guidelines* is not consistent with the nomenclature used in the 1997 NEHRP Provisions.

Section: 2.6 (new section 1.6), Figure 2-1 (new Figure 1-1).

Classification: *Technical Revision.*

Discussion: Differences in nomenclature for the response acceleration parameters S_{XS} and S_{X1} were intentional on the part of the FEMA 273 project team to distinguish parameters that can be related to any selected damping level from those in NEHRP that are related to 5% damping. Differences in nomenclature for period, T_0 and T_S, are not intentional (they were changed in NEHRP after FEMA 273 was published) and should be revised for consistency. In 1997 NEHRP, T_S designates the period at which the constant velocity and constant acceleration portions of the spectrum intersect. T_0 designates the beginning of the region of constant acceleration, taken as $0.2T_S$.

Resolution: The period nomenclature, T_0 and T_S, in Prestandard Section 1.6 has been revised for consistency with the 1997 NEHRP Provisions.

2-16 Inconsistency in Definition of Design Earthquake

The definition of the design earthquake in FEMA 273 is not consistent the design earthquake in the 1997 NEHRP Provisions.

Section: 2.6, 2.6.1.2 (new sections 1.6, 1.6.1.2).

Classification: *Commentary Revision.*

Discussion: The latest MCE hazard maps were developed based on a 2%/50 earthquake hazard level. Because of conservatism present in the actual design of structures there is a margin (seismic margin) against collapse in the event the design level earthquake is exceeded. Popular consensus is that the minimum seismic margin for all buildings is on the order of 150%. This margin is used to set the design values at a level less than if taken directly from the actual hazard. The NEHRP design value is 1/1.5 = 2/3 * MCE. Because of differences in seismicity throughout the country, the variation in probability is not directly proportional to the variation in the response acceleration parameters. This means that applying a 2/3 factor on the MCE results in a design earthquake with a different probability of exceedance at each location, but gives a uniform margin against collapse. However, this is inconsistent with the intent of the *Guidelines*, which is to permit design for specific levels of performance in earthquakes with specific probabilities of exceedance. For this reason the *Guidelines* intentionally adopted a slightly different definition for the design earthquake. BSE-1 was taken as the ground motion with a 10%/50 year probability of exceedance, but not exceeding 2/3 * MCE. The 10%/50 hazard level is consistent with what has traditionally been accepted as the basis for new construction. The 2/3 * MCE limit is included so that the design requirements for the BSO do not exceed the requirements for new construction under the 1997 NEHRP Provisions.

Resolution: The commentary of Prestandard Sections 1.6 and 1.6.1 have been expanded to explain the difference in design earthquakes.

2-17 Incorrect Adjustment for Damping at T=0

Damping adjustments to response spectrum values have been incorrectly applied at T=0.

Section: 2.6.1.5, Eq 2-8, Figure 2-1 (new section 1.6.1.5, Eq 1-8, Figure 1-1).

Classification: *Technical Revision.*

Discussion: Adjustments of response spectrum values for damping should not occur at T=0.

Resolution: Prestandard Equation 1-8 and Figure 1-1 have been revised to correct this.

2-18 Knowledge Factor Requirements Unclear

The requirements for the knowledge factor κ, specified in multiple sections, are unclear.

Section: 2.7.2 (new section 2.2.6.4), 5.3.4, 6.3.4, 7.3.4, 8.3.4.

Classification: *Technical Revision.*

Discussion: This issue is related to issues 5-4 and 6-3 regarding too much required testing. The selection of a knowledge factor depends on the selected analysis procedure, the level of information available on the building, and the amount of testing and condition assessment performed to confirm unknown information. These requirements are distributed throughout multiple sections across different chapters.

Resolution: Prestandard Section 2.2.6 was created to clearly outline data collection requirements. New Table 2-1 was created to provide a matrix of information used for selection of a knowledge factor. New Section 2.2.6.4 was created to centralize requirements for the knowledge factor. Prestandard Sections 5.3.4, 6.3.4, 7.3.4 and 8.3.4 now refer back to Section 2.2.6.4, and contain only knowledge factor information specific to the material in question.

2-19 Upper Limit on DCRs for LSP Needed

There should be an upper limit on DCR values that should not be exceeded if linear procedures are to be applicable, regardless of the presence or absence of structural irregularities.

Section: 2.9.1 (new section 2.4.1).

Classification: *Recommended for Basic Research.*

Discussion: None.

Resolution: Unresolved pending future research.

2-20 General Design Requirements Keyed to BSO

The general analysis and design requirements in Section 2.11 apply to the BSO or Enhanced Rehabilitation Objectives. References to this section in Chapter 3 apply to all rehabilitation objectives. Should application of these requirements be based on performance levels instead?

Section: 2.11 (new section 2.6)

Classification: *Technical Revision.*

Discussion: Related to issue 3-24 regarding redundancy between Sections 2.11 and 3.2. With few exceptions, application of the general design requirements applies to all rehabilitation objectives and would be necessary to achieve Life Safety at any seismic hazard. Therefore, keying application of these requirements to the BSO would be unconservative for a limited objective involving only life-safety performance.

Resolution: Prestandard Section 2.6 has been revised to require application of the general design requirements for systematic rehabilitation to any performance level or seismic hazard, unless otherwise noted. Section 2.11.9 (new Section 2.6.9) regarding common building elements has been revised to apply to all objectives. Application of Section 2.11.10 (new Section 2.6.10) regarding building separation is now keyed to the Life Safety Performance Level.

2-21 Building Separation Requirements Too Severe

The requirements for building separation are too severe, and the analysis required by the *Guidelines* to achieve the BSO is beyond the current state of the practice.

Section: 2.11.10 (new section 2.6.10).

Classification: *Technical Revision.*

Discussion: Related to issue 2-20 regarding general design requirements. Building separation requirements are better keyed to the Life Safety Performance Level. Buildings that are approximately the same height with floor levels that align have demonstrated life safety performance in past earthquakes. The concern for catastrophic damage is really only related to gravity elements, such as columns, that are damaged by impact from misaligned floors, or buildings of substantially different height that impact and alter the distribution of seismic forces in each building.

Resolution: Prestandard Section 2.6.10 has been revised to soften the application of building separation requirements for life safety and lower performance levels when the buildings are substantially the same height and the floor levels align. Prestandard Equation 2-8 has been revised to permit an alternative conservative assumption for adjacent building deflection to simplify calculation.

2-22 **Revise Default Site Class from E to D**

The default site class should be revised from Class E to Class D.

Section: 2.6.1.4 (new section 1.6.1.4).

Classification: *Technical Revision.*

Discussion: The original intent was for the *Guidelines* and the 1997 NEHRP Provisions to be consistent. The *Guidelines* went to print before the Provisions, and a change in default site class was made from Class E to Class D in the Provisions.

Resolution: The default site class specified in Prestandard Section 1.6.1.4 has been revised from Class E to Class D. A new subsection within 1.6.1.4 has been created to clarify the selection of default site class.

2-23 **R_{OT} Needed for IO Performance**

An overturning force reduction factor, R_{OT}, for IO performance is needed to complete the alternative procedure for evaluating overturning stability.

Section: 2.11.4 (new Section 3.2.10.1).

Classification: *Technical Revision and Basic Research.*

Discussion: Related to issue 2-1 regarding conservatism in overturning criteria. The overturning sidebar from the *Guidelines* was incorporated into the Prestandard to provide an analytical method of evaluating overturning that would achieve a level of overturning stability that was consistent with current code procedures for new buildings. The sidebar required the use of full LSP forces for the IO Performance Level. This criteria appears overly conservative in comparison to current code procedures for new hospital construction, which only requires an importance factor of 1.5 on design forces to raise performance to the Immediate Occupancy Level. Using this criteria as a model, R_{OT} has been developed for IO performance as:

$$R_{OT\ (L.S.)}/1.5 = 8/1.5 = 5.3, \text{ and then conservatively reduced to } 4.0.$$

Resolution: Prestandard Section 3.2.10.1, which includes the overturning sidebar discussion from the *Guidelines*, has been revised to include an R_{OT} factor equal to 4.0 for IO performance. Further study is recommended to determine if a value larger than 4.0 may be appropriate.

2-24 **LS Performance Level Should be Clarified or Eliminated**

The Life Safety Performance Level should be more clearly defined in terms of structural performance, or it should be eliminated as a performance goal.

Section: 2.5.1.2 (new Section 1.5.1.2).

Classification: *Recommended for Basic Research.*

Discussion: Defined as retaining a margin against the onset of collapse, the Life Safety Performance Level corresponds to a structural damage state that is not related to a clearly definable post earthquake condition of the building.

Resolution: Unresolved pending future research.

2-25 **The 2/3 Factor Estimating Vertical Seismic Forces is Not Accurate**

The 2/3 factor used to estimate the relationship between vertical response spectra and horizontal response spectra is not accurate.

Section: 2.6.1.5 (new section 1.6.1.5.2)

Classification: *Application of Published Research and Basic Research.*

Discussion: Research presented in a paper by Bozorgnia, et al, "Relationship Between Vertical and Horizontal Response Spectra for the Northridge Earthquake," Eleventh WCEE, 1996, suggests that the 2/3 factor underestimates the ratio between vertical and horizontal spectra for short periods, especially in the near-field region. At longer periods, the 2/3 factor appears to overestimate the ratio.

Resolution: Unresolved pending further study of available information and future research.

2-26 **Additional Guidance on Damping Needed**

There is more variation in damping of actual buildings than addressed in the document. Additional guidance on damping values is needed.

Section: 2.6.1.5 (new section 1.6.1.5.3)

Classification: *Application of Published Research.*

Discussion: Additional guidance on damping for various systems can be found in the Tri-Services Manual. This issue was raised by the SC in response to the unofficial letter ballot of the Prestandard.

Resolution: Unresolved pending further study of available information.

2-27 **Application of Site Coefficients Not Consistent with the IBC**

The application of site coefficients F_a and F_v occurs before application of the 2/3 reduction factor on MCE spectral response acceleration parameters for the BSE-1 earthquake hazard level. This is not consistent with the procedure in the IBC, which applies the coefficients first, and then applies the 2/3 reduction factor.

Section: 2.6.1.1, 2.6.1.2 (new Sections 1.6.1.1, 1.6.1.2)

Classification: *Technical Revision*

Discussion: The selection of site factors F_a and F_v depends on the magnitude of the spectral response acceleration parameters S_s and S_1. As spectral acceleration increases, site factors decrease. Application of the 2/3 reduction factor before selecting the site coefficient in Tables 1-4 and 1-5 will result in the use of more conservative site factors than would be selected in conjunction with the IBC.

Resolution: Prestandard Sections 1.6.1.1 and 1.6.1.2 discussing BSE-1 and BSE-2 parameters S_s and S_1 have been revised to refer to the design spectral response acceleration parameters S_{xs} and S_{x1}, which have been adjusted for site class in accordance with Section 1.6.1.4. The BSE-1 hazard level design parameters will therefore be taken as the minimum of the values calculated using the 10%/50 mapped parameters, or 2/3 of the values calculated using the MCE mapped parameters.

2-28 **Equation for Building Separation is Overconservative**

Equation (2-16) for required building separation based on SRSS combination of building displacements is overconservative.

Section: 2.11.10.1 (new Section 2.6.10.1, Equation 2-8)

Classification: *Application of Published Research*

Discussion: This issue was raised at the 8/23/00 Standards Committee meeting. SRSS combination of maximum estimated building displacements assumes the buildings are moving out-of-phase, with some consideration that the maximum response in each building might occur at different times. While this is less conservative than a direct sum of building displacements, it may overconservative if the buildings are moving under forced oscillations from the same ground motion. It was the opinion of those in attendance that recent published research was available that might justify reduced separation requirements in consideration of potential in-phase response of buildings moving under the same forced input.

Resolution: Unresolved pending further study.

3. Modeling and Analysis

(Systematic Rehabilitation)

Chapter 3 describes modeling and analysis procedures for the systematic evaluation and rehabilitation of buildings. It describes, in detail, four new analysis procedures including the Linear Static Procedure, Linear Dynamic Procedure, Nonlinear Static Procedure and Nonlinear Dynamic Procedure. It addresses loading and mathematical modeling requirements and the basic acceptance criteria.

3.1 New Concepts

- Analysis procedures: The Linear Static, Linear Dynamic, Nonlinear Static and Nonlinear Dynamic procedures are new concepts because they use a displacement-based philosophy addressing the behavior of individual components of the building at the maximum expected displacements of the structure. This philosophy was adopted as being more indicative of actual member performance than traditional force-based analysis procedures. In the linear procedures of the methodology, displacement-based concepts are translated back to force-based calculations to facilitate application by using more familiar procedures.
- Deformation- and force-controlled actions: These concepts were introduced to better define when excess strength can substitute for a lack of ductility. Deformation-controlled actions occur in elements that can undergo inelastic deformation without failure. Force-controlled actions occur in brittle elements or elements that would experience failure when subjected to inelastic deformation. Demands on force-controlled actions are limited by the maximum force that can be delivered to the element due to inelastic activity in the surrounding structure.
- Load combinations: The specified gravity load combinations are intended for seismic evaluation only, and are intentionally smaller than total loads that would be calculated for new buildings. They include the use of 25% of the live load. The resulting total loads are modified because the *Guidelines* require on-site verification of loads so uncertainties are smaller, the building is known to have existed under the loads present, and the performance levels for rehabilitation are not necessarily the same as intended for new construction.
- Mathematical Modeling: Modeling procedures are new concepts because they have never before been prescribed to the level of detail contained in FEMA 273.
- Acceptance criteria: New component-based acceptance criteria have been developed to evaluate components of the lateral force resisting system on an individual basis for deformation- or force-controlled actions considering individual element ductility. Common code-based procedures use a single value for all elements in a building.
- Expected strength: The concept of expected strength was introduced to take full advantage of element capacities at maximum deformation considering overstrength, actual material properties, strain hardening, and composite action. Capacity reduction factors, ϕ, are taken equal to 1.0.
- Lower bound strength: The concept of lower bound strength was developed for force-controlled actions and is the minimum capacity of a force controlled element.
- C factors: The factors C0, C1, C2, and C3, have been introduced to assist in estimating the likely building roof displacement in the design earthquake. The factors make adjustments for higher mode effects, inelastic displacements, shape of the hysteretic behavior of the structure, and P-delta effects.

3.2 Global Issues

3-1 Ct=0.06 for Wood Buildings Not Documented

The accuracy of C_T =0.06 for use in the period calculation for small wood buildings is not documented.

Section: 3.3.1.2, Method 2.

Classification: *Recommended for Basic Research.*

Discussion: The number was selected qualitatively based on some limited case study information and was calibrated to expected results for flexible structures.

Resolution: Unresolved pending future research.

3-2 Application of Method 3 Period Calculation Not Clear

It is not clear that the period calculation for one-story buildings with flexible diaphragms applies to all rigid element flexible diaphragm systems. Calculation of wood diaphragm deflection at 1.0g force level does not appear reasonable.

Section: 3.3.1.2 (new Section 3.3.1.2.3).

Classification: *Technical Revision.*

Discussion: Method 3 applies to all systems in which the response amplification of the ground motion occurs primarily in the flexible diaphragms elements and not in the rigid vertical elements. Use on Method 2 in this situation will significantly underestimate the period of the system and may result in erroneously high pseudo lateral forces. The calculation of period using the diaphragm deflection under a 1.0g force level is a fictitious calculation used for estimating period only. It does not represent actual diaphragm demands or expected displacements. For this calculation the diaphragm is considered to remain elastic.

Resolution: The commentary to Prestandard Section 3.3.1.2 has been expanded to provide additional direction on the use of Method 3. A new Section 3.3.1.2.4 was created to specify a new empirical equation for use specifically with URM buildings.

3-3 Empirical Formulas Underestimate Period

Empirical formulas for period intentionally underestimate building periods and add an unnecessary layer of conservatism to the LSP.

Section: 3.3.1.2.

Classification: *Application of Published Research.*

Discussion: Special Study 3 – Improvements to the FEMA 273 Linear Static Procedure was funded to research this issue. The main conclusion was that using empirical equations yielded conservative results when compared eigenvalue analyses or to measured actual response of buildings. Proposed refinements to empirical equations for period are available in the literature.

Resolution: Method 2 empirical calculation of period in Prestandard Section 3.3.1.2 has been refined to reduce conservatism. The coefficients have been refined to better match measured building performance as recommended in the literature.

3-4 Multidirectional Effects Need Clarification

Further direction on consideration of multidirectional effects, including vertical seismic forces, is required.

Section: 3.2.7.

Classification: *Technical Revision and Basic Research.*

Discussion: When a structure is displaced to its limit state in one direction, there is no reserve capacity to resist additional demands caused by displacements in the perpendicular direction. Also the addition of displacements in perpendicular directions is not intuitive and requires further explanation. It is unclear how to combine the acceptance criteria to elements receiving demands from multiple directions, particularly in the case of non-linear push-over analyses. Special Study 5 – Report on Multidirectional Effects and P-M Interaction on Columns was funded to research this issue. The major conclusions of this study were that information is available in the literature supporting the use of simplified 100% + 30% combinations, but that further research should be conducted in this area.

Resolution: Prestandard Section 3.2.7 was revised to specify code-based 100%+30% combinations for linear procedures. For nonlinear procedures the section was refined to check 100% of the deformations associated with the target displacement in the primary direction plus the forces (not deformations) associated with 30% of the target displacement in the other direction. Prestandard Section 3.2.7.2 was created to state that vertical seismic effects need not be combined with horizontal effects.

3-5 Mass Participation Effects Not Considered

The static analysis procedures do not consider mass participation factors and higher mode effects.

Section: 3.3.1.

Classification: *Application of Published Research.*

Discussion: Static analysis procedures which do not consider mass participation factors overstate the first mode contributions and underestimate the effects of higher modes which are likely out of phase with the primary mode of vibration. Consideration of higher mode effects can reduce the total demand on a structure. Special Study 3 – Improvements to the FEMA 273 Linear Static Procedure was funded to research this issue. The study concluded that the benefits of higher mode mass participation effects are documented in the literature, and were specifically, and conservatively, ignored in the development of the LSP. The effects of higher mode mass participation on building response is dependent on the mass and stiffness characteristics of the structure, so resolution has been keyed to structure type and number of stories.

Resolution: The equation for Pseudo Lateral Load in Prestandard Section 3.3.1.3.1 has been revised to include an new C_m factor to account for higher mode mass participation effects that reduce overall building response. New Table 3-1 was created, which specifies the factor based on structure type and number of stories.

3-6 **NSP Uniform Load Pattern Overly Conservative**

The shape of the loading pattern used in NSP significantly affects the results. Specifying a uniform load pattern appears to be overly conservative and can dominate the resulting behavior.

Section: 3.3.3.2.

Classification: *Technical Revision and Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to perform additional research on nonlinear procedures to consider strength and stiffness irregularities in the structure and improve reliability and accuracy as compared benchmark results. As a structure yields during actual nonlinear response, forces and deformations can redistribute due to changes in stiffness. This effect is not captured by the NSP. Consideration of multiple load patterns is intended to envelope the range possible response. The uniform load pattern is intentionally conservative, and unrelated to what may be actually happening in the yielded structure. Procedures that adapt the load pattern to the yielded structure are available, but currently require more computational effort to apply.

Resolution: Prestandard Section 3.3.3.2.3 has been revised to clarify the application of multiple load patterns and permit the use of an approved adaptive load pattern. Development of simplified adaptive load procedures is recommended for future research.

3-7 **Reconcile FEMA 273 and 310**

The potential difference in evaluation results between FEMA 273 and FEMA 310 should be reconciled.

Section: 3.3.

Classification: *Non-persuasive.*

Discussion: This issue is related to Issue 10-4 regarding differences between FEMA 310 and FEMA 356. Special Study 12 – FEMA 310 and FEMA 356 Differences was funded to research this issue further. FEMA 310 is an evaluation document, while FEMA 273 is a rehabilitation design document. The FEMA 310 Tier 3 detailed evaluation procedure uses 0.75 times the force levels used in FEMA 273. The Tier 2 evaluation procedure uses different *m*-factors. Building components that are compliant at FEMA 310 force levels may not be compliant at full FEMA 273 force levels. This issue stems from the controversial concept that force levels for evaluation should be different (lower) than force levels for design. Because the documents are for different purposes, the differences in the two procedures are intentional. See the discussion on Issue 10-4 for further information.

Resolution: No change proposed.

3-8 URM Special Procedure Not Included

The URM Special Procedure is not included in the *Guidelines*. Some building types, such as URM or tilt-up structures, may be more appropriately evaluated as systems rather than components. Flexible wood diaphragms in rigid wall buildings may need special treatment.

Section: 3.3 (new section 3.3.1.3.5).

Classification: *Technical Revision.*

Discussion: The response amplification of ground motion occurs in the diaphragm of rigid wall flexible diaphragm systems. As such, the behavior of individual components such as wall anchors depends overall system behavior. The Special Procedure was considered and specifically excluded from the *Guidelines*, and Special Study 2 – Analysis of Special Procedure Issues was funded to research this issue. The major conclusions of this study were that the Special Procedure should not be added to the Prestandard, specific portions of the procedure necessary to recognize the unique behavior of URM building should be added, and a revised method to empirically calculate the period of URM buildings is needed.

Resolution: Prestandard Section 3.3.1.3.5 was created to specify a lateral force distribution procedure that considers the unique behavior or URM buildings. A new method for calculating the period of URM buildings was added in Prestandard Section 3.3.1.2.4.

3-9 Reconcile FEMA 273 and Other Procedures

The potential difference in evaluation results between FEMA 273 and other evaluation procedures (other than FEMA 310) should be reconciled.

Section: 3.3.

Classification: *Non-persuasive.*

Discussion: The detailed evaluation procedures described in FEMA 273 may not agree with other procedures that are based more on qualitative information such as engineering judgment or past experience. At the 3/3/99 Standards Committee meeting this issue was reclassified as non-persuasive. A potential resolution would be to assign other procedures to an appropriate FEMA 273 performance level. This idea met with considerable disagreement. It would require bringing all other procedures into the document in some way, directly or by reference, and imply alternative methods for obtaining the same performance.

Resolution: No change proposed.

3-10 **Upper Limit on Pseudo Lateral Force**

The LSP forces appear to be too high. FEMA 273 does not contain an upper bound limit on maximum base shear similar to the 0.75W limit in FEMA 310.

Section: 3.3.1.3.

Classification: *Technical Revision and Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to conduct soil-structure interaction research to study limiting ground motion input to buildings in cases where the ground may not be able to transmit motion through the foundation to the structure. For short and stiff buildings the pseudo lateral force may exceed the force required to cause sliding at the foundation, and the strength of the structure should not need to exceed the capacity of the soil-structure interface. Prestandard Section 3.2.6 provides methods for considering soil-structure-interaction effects.

Resolution: Unresolved pending future research.

3-11 **Clarify Primary, Secondary, Force-, and Deformation-Controlled**

Further explanation and clarification of primary and secondary components and deformation- and force-controlled actions is required.

Section: 2.9.4 (new section 2.4.4), 3.2.2.4, Chapters 5, 6, 7 and 8.

Classification: *Technical and Commentary Revision.*

Discussion: The concepts are partially explained in multiple sections, and the references between sections are circular. Materials chapters are not complete or consistent about specifying the force- or deformation-controlled nature of component actions.

Resolution: The definitions of primary and secondary components and deformation- and force-controlled actions have been centralized in Prestandard Section 2.4.4. The commentary has been expanded to further clarify the distinction. Materials Chapters 5 through 8 have been editorially clarified to specify force- or deformation-controlled actions for components.

3-12 **Reference to Alternative NSP Procedures Needed**

The *Guidelines* utilize the target displacement, or coefficient, method of evaluating nonlinear response, and do not include other alternative methods for performing nonlinear analyses.

Section: 3.3.3.3.

Classification: *Commentary Revision.*

Discussion: The Commentary in FEMA 274 describes the Capacity Spectrum Method as an acceptable alternative, but this procedure has not been directly incorporated into the analysis methodology of the *Guidelines*.

Resolution: Commentary has been added to Prestandard Section 3.3.3.3.2 to reference the Capacity Spectrum Method as an acceptable alternative method for nonlinear analysis.

3-13 **LSP and NSP Results Need Calibration**

The Linear Static Procedure is not always more conservative than Nonlinear Static Procedure.

Section: 3.3.1.

Classification: *Recommended for Basic Research.*

Discussion: The concern is that a building passing the LSP may fail the NSP. It is generally expected that simplified methods yield more conservative results so that a reduction in conservatism can then be achieved with additional computational effort.

Resolution: Unresolved pending future research.

3-14 **Reliability Information Not Provided**

No specific information on reliability is provided in the *Guidelines*.

Section: 3.3.

Classification: *Recommended for Basic Research (previously unresolved).*

Discussion: No procedures exist for taking reliability into account in setting parameters or performing evaluations. Upon completion of the *Guidelines*, BSSC identified the need to perform reliability studies using statistical techniques to develop the degree to which rehabilitation objectives could be met.

Resolution: Unresolved pending future research.

3-15 **LSP Should be a Displacement Calculation**

The Linear Static Procedure should be changed to a displacement-based calculation procedure.

Section: 3.3.1.

Classification: *Non-persuasive.*

Discussion: The LSP is a displacement-based procedure that has been translated back to force-based calculations for simplicity. The concern is that the use of force-based calculations hides the real intent of the displacement-based philosophy and is confusing to engineers who are used to dealing with lower magnitude forces. Special Study 3 – Improvements to the FEMA 273 Linear Static Procedure was funded to research this issue, but was unsuccessful in developing a simplified displacement-based calculation procedure for incorporation into the Prestandard. At the 3/3/99 Standards Committee meeting this issue was reclassified as non-persuasive.

Resolution: No change proposed.

3-16 **Combined with 2-2, 3-5, 3-6**

Combined with Global Issues 2-2, 3-5, 3-6 and omitted.

Section: None.

Classification: *None.*

Discussion: None.

Resolution: None.

3-17 **C1 Factor Overly Conservative**

Introduction of the C_1 factor overly penalizes buildings with short calculated fundamental periods.

Section: 3.3.3.3.

Classification: *Recommended for Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to research the effects of foundation flexibility on increasing the period of short and stiff structures and the associated impact on the C_1 factor.

Resolution: Unresolved pending future research.

3-18 **Duration Effects Not Considered**

The analytical procedures of the *Guidelines* do not consider duration effects to take into account cyclic degradation.

Section: 3.3.

Classification: *Recommended for Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to develop simplified methods for establishing degraded pushover properties and approximating complex duration effects.

Resolution: Unresolved pending future research.

3-19 **Marginal Gravity Load Capacity Not Considered**

Further study of LSP acceptance criteria is required for building components with marginal gravity load capacity.

Section: 3.4.2.

Classification: *Recommended for Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to further research this issue.

Resolution: Unresolved pending future research.

3-20 **Inelastic Cyclic Properties Needed**

More information is needed to develop inelastic cyclic component properties for use in complex nonlinear dynamic analyses.

Section: 3.3.4.

Classification: *Recommended for Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to develop consensus models for inelastic cyclic behavior of components.

Resolution: Unresolved pending future research.

3-21 **Combined with 3-10**

Combined with Global Issue 3-10 and omitted.

Section: None.

Classification: *None.*

Discussion: None.

Resolution: None.

3-22 **Amplification of Torsion Needs Clarification**

The definition of torsion and the procedure for amplification of torsion need further clarification.

Section: 3.2.2.2.

Classification: *Technical Revision.*

Discussion: The current definition does not discuss dynamic torsion, or torsion due to rotational modes of building response. This is a dynamic characteristic of the system that may produce torsion in excess of that due to eccentricity between the center of mass and center of rigidity. Currently the *Guidelines* only require accidental torsion to be amplified.

Resolution: Resolution expected, but not yet developed.

3-23 **Substantiation of C1, C2, C3 Needed**

Further research is needed to substantiate the coefficients C_1, C_2, and C_3.

Section: 3.3.1, 3.3.3.

Classification: *Commentary Revision and Basic Research.*

Discussion: Special study 7 – Report on Study of C-Coefficients was funded to research this issue, resulting in minor clarifications to C coefficient definitions and additional commentary.

Resolution: Commentary from FEMA 274 has been added to Prestandard Section 3.3.1.3.1, and definitions in Section 3.3.3.3.2 have been clarified for consistency. Further resolution of this issue is recommended for future research.

3-24 **Reorganization of Sections 3.2 and 2.11**

Overlap and redundancy between Sections 3.2 and 2.11 (new section 2.6) makes it difficult to find and apply general analysis and design provisions applicable to a given rehabilitation project.

Section: 3.2, 2.11 (new section 2.6).

Classification: *Editorial Revision.*

Discussion: None.

Resolution: Information contained in these sections has been combined and reorganized in the Prestandard so that Section 2.6 contains general design provisions applicable to any rehabilitation project, and Section 3.2 now contains general analysis provisions needed to properly apply the analysis procedures.

3-25 **Definition of Pushover Curve Not Complete**

The idealized force-displacement curve shown in Figure 3-1 is not well defined. Further guidance is needed to properly, and consistently, define the pushover curve.

Section: 3.3.3.2 (new section 3.3.3.2.4).

Classification: *Technical Revision.*

Discussion: The idealized force-displacement curve is used to set the effective stiffness and, in turn, calculate the target displacement. Consistent definition of this curve is necessary for proper application of the NSP.

Resolution: Prestandard Section 3.3.3.2.4 has been revised to better define the construction of the idealized curve. Revisions include balancing the area above and below the actual curve, and requiring the idealized curve to pass through the actual curve at the calculated target displacement.

3-26 **Application of the *J*-factor Not Clear**

The technical justification and proper application of the *J*-factor is not clear. It is also not clear why the *J*-factor should be related to the spectral response coefficient S_{XS}, in Equation 3-17.

Section: 3.4.2.1, Equation 3-17 (new Equation 3-21).

Classification *Commentary Revision and Basic Research.*

Discussion: The technical justification of the J-factor is not described in the FEMA 274 *Commentary*. Consequently the factor is not widely understood. For force-controlled actions, the preferred method to calculate demands is a limit state analysis to determine the maximum force that can be delivered to a component. The intent of the *J*-factor is to provide an alternative method of calculating the maximum demand based on the pseudo lateral force. The *J*-factor is a force reduction factor that limits forces on components due to nonlinear actions on other ductile components in the system. It is intended to account for ductility inherent in systems that have elements that are behaving inelastically, even if the component under consideration is nonductile. The concept of a limit state analysis means that the maximum force delivered to a component is not governed by the severity of the ground motion. In the original *Guidelines*, *J* was related to S_{XS}, so that when it was used in Equation 3-15 (new Equation 3-19) the resulting force was also not dependent on the severity of the ground motion. At the 2/15/00 Standards Committee meeting, the committee voted to delete Equation 3-17 (new Equation 3-21) relating *J* to S_{XS}. The PT concurs that relating *J* to S_{XS} is questionable. It does, however, feels that the concept of a force-reduction factor is appropriate, and that some more appropriate formulation of it should remain in the Prestandard.

Resolution: The commentary to prestandard Section 3.4.2.1 has been expanded to reflect the above discussion. Prestandard Equation 3-21 relating *J* to S_{XS} has been deleted and replaced with a revised Section 3.4.2.1 that provides values of *J* judged to be conservative, and emphasizes the use of DCR values in the load path which is more rational. Further study on this issue is recommended.

3-27 Degradation Effects Double Counted in LSP

Calculation of demands in the *Guidelines* analysis procedures include coefficients that account for degradation, but acceptance criteria do not permit components to respond beyond the elastic or plastic limits of response.

Section: 2.9.4 (new section 2.4.4), 3.3.1.

Classification: *Technical Revision.*

Discussion: Coefficients C_2 and C_3 are intended to account, in part, for increased displacements caused by degradation of components or the structural system. Component load-deformation curves in Figure 2-5, and acceptance criteria specified in 2.9.4, state that acceptance for primary elements is within the elastic or plastic portions of response, so components meeting the acceptance criteria will not experience degradation that would lead to increased displacements. Special Study 3 – Improvements to the FEMA 273 Linear Static Procedure was funded to research this issue. The main conclusion was that the effects of component degradation are counted on both the demand side as well as the capacity side of the equation for acceptance, and that this conservatism should be eliminated.

Resolution: The definition of C_2 in Prestandard Section 3.3.1.3.1 has been revised so that the coefficient is taken as 1.0 for linear procedures.

3-28 Global Acceptance Criteria Needed

Tracking acceptance on a component basis is conservative with respect to overall building behavior. Global nonlinear acceptance criteria are needed to better calibrate observed performance with performance predicted by the procedures in the *Guidelines*.

Section: 3.3.3.2, 3.4.3.2.

Classification: *Technical Revision.*

Discussion: This issue is related to 3-27, and was studied as part of Special Study 3 – Improvements to the FEMA 273 Linear Static Procedure. The main conclusion was that a global nonlinear analysis criterion was needed. Further study concluded that a global criteria was implicit in the current NSP procedure, but not explicitly defined or well understood. If all components are modeled with full degrading backbone curves, the effects of component degradation can be evaluated in the analysis, and acceptance can be permitted out to secondary component limits of response.

Resolution: Prestandard Section 3.3.3.2 was expanded to clarify modeling requirements, including the use of full component backbone curves. The concept of a simplified NSP analysis was introduced for situations where degradation cannot be modeled. The acceptance criteria of Section 3.4.3.2 was revised to permit acceptance out to secondary component limits of response when degradation is explicitly modeled. A new Section 3.4.3.2.2 was created to define acceptance criteria for the simplified NSP analysis.

3-29 **Snow Load Should be Specified**

The *Guidelines* are not specific regarding the magnitude of snow load to be considered in combination with seismic forces.

Section: 3.3.1.3 (new Section 3.3.1.3.1).

Classification: *Technical Revision.*

Discussion: This issue was raised at the 2/15/00 Standards Committee meeting. It is considered critical in regions with large snowpack. The verbiage incorporated in the Prestandard was based on the 1997 NEHRP Provisions, with permissive language allowing the reduction of snow loads with the approval of the local jurisdiction. The issue is that a more definitive statement on the amount of snow load to be considered in the calculation of seismic weight is needed in the Prestandard. The IBC, which specifies 20% of snow loads exceeding 30 psf, was recommended as a source for information on an appropriate snow load.

Resolution: The definition of snow load to be considered in the calculation of seismic weight has been revised to match the IBC. The permissive language regarding reduction of the snow load has been replaced with the specification of 20% of snow loads exceeding 30psf.

3-30 **Application of η-factor is Overconservative**

Amplifying forces and displacements by the η-factor to account for torsion is overconservative for lateral force resisting elements located near the center of rigidity.

Section: 3.2.2.2 (new Section 3.2.2.2.2).

Classification: *Recommended for Basic Research.*

Discussion: Lateral force resisting elements located near the center of rigidity will not experience the same increase in forces and displacements as elements located farther away. It is suggested that η should vary with distance between the element and the center of rigidity.

Resolution: Unresolved pending further study.

3-31 Consider Reduced Demands Due to Actual Torsion

Actual torsion will reduce the demands on some elements. It is overconservative and analytically difficult when using finite element programs to require that torsion never reduce the total demand on an element.

Section: 3.2.2.2 (new Section 3.2.2.2.2).

Classification: *Technical Revision.*

Discussion: Actual torsion is due to the actual eccentricity between the centers of mass and rigidity in the structure. This eccentricity is a source of real torsion that always adds to the critical elements and subtracts from the non-critical ones. When modeling in 3-D, it is analytically difficult to make sure the actual torsion does not reduce the demand on some elements. Uncertainty in torsion is addressed by accidental torsion. Since this torsion is uncertain in nature, it makes sense that accidental torsion effects should never reduce the demands on a component. It is recommended that only accidental torsion fall under this requirement.

Resolution: Prestandard Section 3.2.2.2.2 has been revised to specify that only accidental torsion shall not be used to reduce force and deformation demands on components.

3-32 No Maximum Limit on Method 1 Period

Method 1 for analytical calculation of period has no maximum limit.

Section: 3.3.1.2.

Classification: *Commentary Revision.*

Discussion: Codes for new buildings include an upper limit on periods determined using analytical methods in order to maintain a minimum design base shear. Prestandard Method 1 calculation of period using eigenvalue analysis has no upper bound limit. Use of analytically calculated period to determine design actions without limit was intentionally permitted in the *Guidelines* to encourage more advanced analyses and reward additional computational effort. It was thought that sufficient controls are present in analysis procedures and acceptance criteria to yield appropriate results.

Resolution: Commentary to Prestandard Section 3.3.1.2 regarding Method 1 has been expanded to explain this departure from current code procedures.

3-33 Omit C2 Factor For Nonlinear Procedures

The C2 factor should be omitted for nonlinear procedures because recent research has shown that inelastic displacements are not significantly affected by the pinched hysteretic behavior of components.

Section: 3.3.3.3.2.

Classification: *Technical Revision and Basic Research.*

Discussion: Related to issue 3-27 regarding degradation effects in the LSP. The C2 factor is intended to account for increased inelastic displacements due to pinched hysteretic behavior, stiffness deterioration and strength degradation of components. Recent research in SAC state of the art reports indicates that hysteretic behavior does not significantly affect inelastic displacements. Since the C3 factor already amplifies displacements for global strength and stiffness deterioration of the system, a direct result of component deterioration, current consensus is that the C2 factor can be eliminated. At the 2/15/00 Standards Committee meeting the committee voted to omit the C2 factor. The Prestandard has been revised to permit the use of C2=1.0 for nonlinear procedures, however, the original formulation of the factor has been preserved in the document because the information is new and evolving. Further research is recommended to confirm the relationship between inelastic displacements and component hysteretic behavior.

Resolution: The definition of C2 for nonlinear procedures has been revised to permit the use of C2=1.0. The commentary to Prestandard Section 3.3.3.3.2 has been expanded to reflect the above discussion.

3-34 Alternate Empirical Period Calculation for Flexible Diaphragms

An alternate empirical equation can be developed for single span flexible diaphragms consisting of $T=C_{td}\,(L)^{1/2}$, where L is the span length and C_{td} is a materials based coefficient.

Section: 3.3.1.2.3

Classification: *Application of Published Research.*

Discussion: This formulation was proposed as an alternate to the current Method 3 period calculation in response to the unofficial letter ballot of the Prestandard distributed to the SC. The proposed equation is based on preliminary studies made by Freeman, et al.

Resolution: Unresolved pending further study of available information and future research.

3-35 **Omit C_1 C_2 C_3 Factors from the Denominator of Diaphragm F_p**

The presence of C_1 C_2 and C_3 in the denominator of the equation for diaphragm F_p forces is not consistent with the calculation of force- or deformation-controlled demands with the acceptance criteria of Section 3.4.

Section: 3.3.1.3 (new section 3.3.1.3.4, Equation 3-13)

Classification: *Technical Revision.*

Discussion: Chapters 5 through 8 provide specific direction regarding consideration of force- or deformation-controlled actions on diaphragm components. Calculation of forces using Equation 3-13 is not consistent with force- or deformation-controlled acceptance criteria in Section 3.4. Equation 3-22 would permit the use of m-factors with Fp forces reduced by C_1 C_2 C_3 for deformation –controlled actions, and Equation 3-19 would permit the further reduction of Fp forces by C_1 C_2 and C_3 a second time for force-controlled actions. This issue was raised by the SC in response to the unofficial letter ballot of the Prestandard.

Resolution: Prestandard Equation 3-13 has been revised to omit the factors from the denominator. Section 3.3.1.3.4 has been expanded to reference Chapters 5 through 8 for direction on force- or deformation-controlled actions.

3-36 **Application of the NSP With Non-Rigid Diaphragms Needs Revision**

Further guidance is required on the proper application of the NSP in buildings with non-rigid diaphragms.

Section: 3.3.3.3 (new section 3.3.3.3.1)

Classification: *Recommended for Basic Research.*

Discussion: In buildings with non-rigid diaphragms, some of the deformation demand can be taken up in diaphragm deflection. This could be unconservative in estimating deformation demands on vertical seismic framing elements. To approximately account for this, original FEMA 273 included provisions for amplifying the calculated target displacement by the ratio of the maximum diaphragm displacement to the displacement at the center of mass. However, pushing the vertical elements to the full target without consideration of diaphragm deflections is overconservative. Development of methods to explicitly apply the NSP to non-rigid diaphragms is recommended. The solution may center around the development of C_0 factors relating horizontal displacements along the length of the diaphragm or revising the control node location to push the third points of the diaphragm to the target.

Resolution: Unresolved pending future research.

3-37 **C_0 Factors Overconservative for Uniform Load Pattern**

Pushing buildings with the uniform load pattern to target displacements calculated using C0 factors based on an inverted triangular load pattern is overconservative.

Section: 3.3.3.3

Classification: *Technical Revision.*

Discussion: The current C_0 factors were developed for an inverted triangular distribution of loading, which is essentially the first mode response with all floors moving in phase. The uniform load pattern is intended to capture higher mode effects, which occur when floors are moving out of phase. In buildings responding dynamically in a manner consistent with the uniform load pattern, the relationship between the spectral displacement of the equivalent SDOF system and the roof displacement of the actual MDOF system will be different (lower) than the case of a triangular distribution. Additional C_0 factors specific to the uniform load pattern should be developed.

Resolution: Prestandard Table 3-2 has been revised and expanded to consider buildings dominated by shear or cantilever behavior, and to include reduced values for the uniform load pattern in the case of shear buildings. The commentary has been expanded to explain that explicit calculation of C_0 is preferred and could be beneficial.

3-38 **Procedures for Torsional Amplification are Unconservative**

Procedures for torsional amplification do not account for torsional degradation and are unconservative in determining increased forces and displacements for this effect.

Section: 3.2.2.2

Classification: *Recommended for Basic Research*

Discussion: This issue was raised at the 8/23/00 Standards Committee meeting. Traditional practice has permitted the analysis of buildings along each principle axis independently. Reportedly there have been recent studies in Japan indicating that further amplification of forces and displacements is required to properly account for torsion as the stiffness of the structure degrades in the direction perpendicular to the direction under consideration. This issue is related to issue 3-30 which suggests that current procedures are overconservative.

Resolution: Unresolved pending future research.

4. Foundation and Geotechnical Hazards (Systematic Rehabilitation)

Chapter 4 provides guidance on geotechnical aspects of foundations and site hazards. It describes acceptability criteria for foundation systems and foundation soils. It includes procedures for developing soil design and analysis parameters.

4.1 New Concepts

- Soil cannot fail: The procedures contained in the *Guidelines* presume that the soil will not be susceptible to a significant loss in strength due to earthquake loading. Soils such as this will continue to mobilize load with increasing deformations after reaching ultimate soil capacity. The amount of acceptable soil deformation depends primarily on the effect of the deformation on the structure, and the two cannot be evaluated independently. If the soil underlying the building in question is subject to strength loss, the resulting structural deformations must be explicitly considered in the evaluation.
- Mitigation of site hazards: Site hazard mitigation is considered in the context of overall building performance. If the consequences of fault rupture, liquefaction, differential settlement, landslide or flood result in excessive structural deformations that do not meet the performance level, mitigation is recommended. Methods of site hazard mitigation are listed.
- Consideration of seismic forces on retaining walls: In general, past earthquakes have not caused damage to building walls below grade. The *Guidelines*, however, include guidance on conditions for which it may be advisable to check walls for seismic demands such as poor construction, light reinforcement, use of archaic materials, or the presence of damage.

4.2 Global Issues

4-1 **Spring Limitations Required in NSP**

Some of the problems identified in a NSP analysis can be fixed by the addition of foundation springs in the analysis. There is insufficient guidance on the limitations in the application of foundation springs to increase building flexibility.

Section: 4.4, 3.2.6

Classification: *Technical Revision*

Discussion: The addition of foundation springs, if sufficiently flexible, can provide additional displacement capacity to reach the target displacement without exceeding structural deformation limits. Special Study 4 – Foundation Issues was funded to research this issue further. The main conclusion of this study was that additional limitations on the use of soil-structure interaction (SSI) with the NSP are not required. Additional flexibility in the system will increase the target displacement, which can make it more difficult to achieve the desired performance, even when that flexibility is coming from the foundation level. The study also concluded that the intent of the original 25% limitation on maximum reduction due to SSI effects in Section 3.2.6 applies to linear procedure only. If the results of an NSP analysis are bounded by parametric studies of soil parameters, this limitation is not needed.

Resolution: Prestandard Section 3.2.6 has been revised to limit the 25% maximum reduction due to SSI effects to linear procedures only. No other changes proposed.

4-2 Spring Procedure Not Applicable to Strip Footings

The procedure for developing foundation spring constants using an equivalent circular footing is not directly applicable to strip footings below shear walls.

Section: 4.4.2.1, Figures 4-2, 4-3 (new Figures 4-4 and C4-1).

Classification: *Application of Published Research.*

Discussion: At the 3/3/99 Standards Committee meeting this issue was reclassified as recommended for basic research. Special Study 4 – Foundation Issues was funded to research this issue further. The study concluded that new spring stiffness solutions directly applicable to a general rectangular footing of any size are available in the literature, and can be incorporated into the Prestandard.

Resolution: Prestandard Figure 4-4 has been revised to include new equations for spring constants that are directly applicable to rectangular footings. Figure C4-1 is a graphical representation of information in the equations that has been added to the commentary for information only.

4-3 Lateral Soil Spring Procedure Needs Refinement

The procedure for developing lateral soil spring stiffness based on displacement results in unrealistically high calculated lateral soil pressures. More information is needed on the force-displacement behavior of geotechnical materials and foundations under short term loading.

Section: 4.4.2.1.

Classification: *Application of Published Research and Basic Research (previously unresolved).*

Discussion: Geotechnical engineering has traditionally focused on long-term force-displacement behavior of soils. Upon completion of the *Guidelines*, BSSC identified the need to conduct additional research on characteristics of soils under short term loading. Special Study 4 – Foundation Issues was funded to research this issue further. The study concluded that the *Guidelines* procedure for developing lateral soil springs at a certain displacement implies that unrealistically high passive pressures are developed in the soil. A revised formulation for lateral strength due to passive pressure and base traction is included.

Resolution: Prestandard Section 4.4.2.1.5 has been revised to specify the use of principles of soil mechanics to determine the lateral capacity of shallow foundations. The commentary has been expanded to provide guidance on this.

4-4 Nonlinear Soil Spring Information Needed

More information is needed on nonlinear force-displacement behavior of foundation systems for inclusion in nonlinear analyses.

Section: 4.4.2.1, Figure 4-4 (new Figure 4-6).

Classification: *Application of Published Research and Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to conduct additional research on this issue. Special Study 4 – Foundation Issues was funded to research this issue further. The study concluded that the present linear relationship for passive pressure mobilization shown in *Guidelines* Figure 4-4 is unrealistic. The actual relationship is highly nonlinear.

Resolution: Prestandard Figure 4-6 has been revised to reflect the actual nonlinear relationship for mobilization of passive pressure.

4-5 Shear Modulus Factors Inconsistent with NEHRP

Shear modulus reduction factors presented in Table 4-3 are significantly different from those presented in Table 5.5.2.1.1 of the 1997 NEHRP Provisions.

Section: 4.4.2.1, Table 4-3 (new Table 4-7).

Classification: *Technical Revision.*

Discussion: Special Study 4 – Foundation Issues was funded to research this issue further. The study concluded that the values in Table 4-3 should be revised to reflect recent research on the subject, consider sensitivity to realistic variation in key parameters, and reflect softening of soils due to free-field response and inertial interaction.

Resolution: Values of effective shear modulus in Prestandard Table 4-7 have been revised in accordance with this research.

4-6 Soil Parametric Range Appears Extreme

Variation in soil parameters by factors of ½ and 2 appears to be extreme. A more appropriate range between upper and lower bound should be specified.

Section: 4.4.2.

Classification: *Non-persuasive.*

Discussion: Special Study 4 – Foundation Issues was funded to research this issue further. Variation in soil parameters is intended to account for many factors including rate of loading, assumed elasto-plastic soil behavior, cyclic loading, and variability of soil properties. The study concluded that variation in parameters of ½ and 2 is consistent with other standards, and is appropriate. With additional soil investigation, this factor could be reduced to 1.5.

Resolution: No change proposed.

4-7 **Classification of Foundation Rigidity**

Quantitative guidance on the classification of foundations as rigid or flexible with respect to the underlying soil is required.

Section: 4.4.2.1.

Classification: *Application of Published Research.*

Discussion: Special Study 4 – Foundation Issues was funded to research this issue further. The commentary of Prestandard Section 4.4.2.1.1 has been expanded to provide guidance on the classification of foundations as rigid or flexible with respect to the underlying soil.

Resolution: The commentary of Prestandard Section 4.4.2.1.1 has been expanded to provide guidance on the classification of foundations as rigid or flexible with respect to the underlying soil.

4-8 **Guidance for Rocking Needed**

Although rocking behavior is discussed in Section C4.4.2.1 of FEMA 274, no guidance is provided on the inclusion of such behavior in the analysis procedures of the *Guidelines*.

Section: 4.4.

Classification: *Application of Published Research.*

Discussion: Special Study 4 – Foundation Issues was funded to research this issue further. The study presented an outline of a response spectrum design approach for considering rocking, based research published in the literature. This information has not yet been incorporated into the Prestandard.

Resolution: Commentary has been added to Prestandard Section 4.4.2 to provide guidance on how to consider rocking when using the LSP. References to published literature on rocking have been added to Section C4.9.

4-9 **Presumptive Values for Piles Missing**

Information on presumptive capacities for pile foundations is not included in the *Guidelines*.

Section: 4.4.1.

Classification: *Application of Published Research.*

Discussion: Special Study 8 – Incorporation of Selected Portions of Recent Related Documents was funded to research this issue further. Information on presumptive capacities of pile foundations is available in ATC-43.

Resolution: Information on presumptive capacities for pile foundations has been added to Prestandard Section 4.4.1.1.

5. Steel and Cast Iron

(Systematic Rehabilitation)

Chapter 5 provides guidance on systematic rehabilitation of steel structural systems including moment frames, braced frames, plate shear walls and steel frames with infill. It includes procedures for obtaining material properties and the condition assessment of steel structures, and describes the acceptance criteria for steel components.

5.1 New Concepts

- Cast iron values: The *Guidelines* include design values for evaluating the capacity of cast iron elements
- Brittle connections: *m*-values have been specified for fully restrained welded moment connections, permitting limited inelastic activity on potentially brittle elements.
- Testing requirements: The *Guidelines* include new requirements on testing and condition assessment for determination of design and analysis parameters for steel structures.
- Rehabilitation measures: The procedure includes a discussion of possible rehabilitation strategies to address deficiencies identified in various steel structural systems.

5.2 Global Issues

5-1 ***m*-factors Appear Overly Conservative**

Certain values of acceptance criteria (*m*-factors) and deformation limits for steel components appear to be too conservative.

Section: Tables 5-3, 5-4, 5-5, 5-6, 5-7, 5-8; Sections 5.8.x.3.

Classification: *Recommended for Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to augment data used to develop acceptance criteria. Existing values were determined on a rational basis using available experimental results. This issue is related to issue 2-6 regarding baselining of acceptance criteria. Special Study 6 – Acceptability Criteria (Anomalous *m*-values) was funded to research this issue. The results of this study are still under consideration by the Project Team. Changes to *m*-factor tables in Chapter 5 are on hold pending further discussion.

Resolution: Unresolved pending future research.

5-2 Steel Default Values Too Low

Default expected material strength values for steel are too low.

Section: 5.3.2.5.

Classification: *Technical Revision.*

Discussion: This issue is related to issue A-7 regarding expected and lower bound strengths. Default expected values for steel in the *Guidelines* have been conservatively set at mean less two standard deviations. In general, however, default values in the *Guidelines* are intended to be lower bound, not expected material properties. Use of default values as expected strengths in Chapter 5 is not consistent with section 2.9.4 or other material chapters.

Resolution: Tables of default values in Prestandard Chapter 5 have been revised to reflect lower bound material strengths. Values were conservatively based on historic data using mean less two standard deviations. Values remain unchanged, but have been assigned to lower bound properties.

5-3 Insufficient Limits for Cast Iron

There are not enough limitations on using cast iron to resist seismic forces, particularly in bending.

Section: 5.4.2.3, 5.4.3.3, 5.5.2.3, 5.5.3.3.

Classification: *Technical Revision.*

Discussion: Except for a few locations, cast iron is not explicitly discussed. Tables of acceptance criteria do not clearly distinguish between steel and cast iron, which have very different responses to inelastic deformations.

Resolution: Cast iron requirements were centralized in Prestandard Section 5.11. This section clearly prohibits the use of cast iron components as primary elements of the lateral force resisting system.

5-4 **Too Much Testing is Required**

The *Guidelines* require too much testing of in-place materials for the determination of design and analysis parameters.

Section: 5.3.2, 5.3.3.

Classification: *Technical Revision (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to develop non-destructive test and inspection procedures for in-situ evaluation of materials. This issue is related to issues 2-18 and 6-3 regarding knowledge factor and too much required testing of concrete. Acceptance criteria depend on reliable knowledge of the material properties and condition of the components. Nonlinear procedures in particular require an in-depth understanding of the condition and material properties of components. Testing and condition assessment decreases the potential uncertainty and increases the reliability of results. However, the level of testing and destructive condition assessment specified in the *Guidelines* is extreme, and far in excess of standard practice. The amount of required testing is related to the selected analysis procedure, the level of information available on the building and the knowledge factor used in the analysis.

Resolution: Prestandard Section 2.2.6 was created to clearly outline data collection requirements. Minimum, comprehensive, and a new classification called usual data collection have been clearly defined. New provisions for usual data collection in Prestandard Sections 5.3.2 and 5.3.3 are intended to match current standard practice with regard to testing and condition assessment. Original FEMA 273 materials testing and destructive condition assessment provisions have been assigned to comprehensive data collection. New Table 2-1 was created to provide a matrix of information used for determination of testing requirements as related to rehabilitation objective, analysis procedure and knowledge factor

5-5 **Presentation by System Type is Redundant**

The presentation of material evaluation and acceptance criteria by system type, such as moment frame, braced frame, etc. is redundant, difficult to follow, and makes it difficult to compare the criteria for each system

Section: 5.4, 5.5, 5.6, 5.7, 5.8, 5.

Classification: *Non-persuasive.*

Discussion: This change would require editorial reorganization of information in all materials chapters. At the 3/3/99 Standards Committee meeting this issue was reclassified as non-persuasive.

Resolution: No change proposed.

5-6 **Aluminum is Not Included**

Parameters for design, analysis and acceptance of aluminum structural systems are not included in the document.

Section: 5.4, 5.5, 5.6, 5.7, 5.8, 5.9.

Classification: *Non-persuasive.*

Discussion: At the 3/3/99 Standards Committee meeting this issue was reclassified as non-persuasive. The infrequent occurrence of aluminum in lateral force resisting systems does not warrant further consideration of this issue.

Resolution: No change proposed.

5-7 **Infill Evaluation Criteria Not Complete**

The *Guidelines* reference Chapters 6 and 7 for acceptance criteria when addressing steel frame structures with infills. The procedures in other materials chapters are not fully developed and not directly applicable for evaluating steel frame elements in infill systems.

Section: 5.7 (new section 5.8).

Classification: *Commentary Revision.*

Discussion: At the 3/3/99 Standards Committee meeting this issue was reclassified as commentary revision. It was the consensus opinion that the necessary information is already contained within the *Guidelines,* but that additional commentary could be added to further clarify the procedures.

Resolution: Commentary to Prestandard Section 5.8 has been expanded to provide additional direction regarding steel frame with infills.

5-8 **Inconsistent Specification of Acceptance Criteria**

The specification of acceptance criteria in Chapter 5 is inconsistent with the criteria specified in Chapter 6.

Section: 5.4, 5.5, 5.6, 5.7, 5.8, 5.9.

Classification: *Technical Revision.*

Discussion: Chapter 5 specifies deformation ratios (Δ/Δ_y), whereas Chapter 6 specifies deformation limits (maximum plastic hinge rotations). Ideally the acceptance criteria should be specified in the same way for similar actions in all materials. Special Study 9, Incorporating the Results of the SAC Joint Venture Steel Moment Frame Project was funded to research this issue further. Related to issue 5-14 regarding the relationship between Chapter 5 acceptance criteria and component length.

Resolution: Prestandard Table 5-6 containing nonlinear acceptance criteria for steel components has been revised to provide plastic hinge rotations or plastic deformation limits in a format that is more consistent with other chapters.

5-9 *m*-factors Less Than 1.0 Too Low

Component modification factors (*m*-factors) less than 1.0 are specified for some brittle components of significant concern. Values less than 1.0 imply these components require strengths in excess of pseudo lateral force elastic demands, which does not make sense.

Section: 5.4.2.3, 5.4.3.3, 5.5.2.3, 5.5.3.3, 5.6.3, 5.9.3

Classification: *Technical Revision.*

Discussion: None.

Resolution: Prestandard Tables in Chapter 5 have been revised so that all *m*-factors less than 1.0 are set equal to 1.0. Notes requiring the use of tabulated values divided by 2.0 have been revised to specify $m=1.0$ as a minimum value. Similarly, deformation ductility ratios for nonlinear acceptance criteria that were less than 1.0 have been revised to a minimum of 1.0.

5-10 Chapter 5 Acceptance Criteria Inconsistent and Unclear

The acceptance criteria in Chapter 5 tables of *m*-factors and deformation limits is internally inconsistent and appears to contain errors. The treatment of P-M interaction needs clarification.

Section: 5.4, 5.5, 5.6, 5.7, 5.8, 5.9, Tables — all.

Classification: *Technical Revision.*

Discussion: The treatment of axial loads on beam-columns needs clarification. IO requirements for braces are more stringent than columns. Table headings are inconsistent with tabular values and it is unclear what the entries are intended to be.

Resolution: Prestandard Chapter 5 has been revised to correct these issues. Table headings and entries have been clarified and corrected based on errata published by ATC on November 2, 1999. Prestandard Section 5.5.2.4 has been revised to clarify beam-column acceptability requirements.

5-11 **Guidance on calculation of strength of anchor bolts needed**

Guidance on calculating the strength of anchor bolts is needed.

Section: 5.4, 5.5, 5.6

Classification: *Technical Revision*

Discussion: Prestandard Section 5.5 on FR frames references the limit states to be considered at the interface between steel columns and concrete foundations. (Sections for other systems reference FR frames as the basis for strength and acceptability calculations.) These limit states include consideration of anchor bolt bond to concrete, and failure of concrete. A new procedure for calculation of anchor bolt strength called the Concrete Capacity Design (CCD) Method has been developed and incorporated in Section 1916 of the IBC. The procedure explicitly evaluates the various failure states of the steel anchor or the concrete. Anchor bolt failure modes related to concrete failures should be treated as force controlled actions. Related to issue 5-16 regarding permissible nonlinearity in column base plates.

Resolution: Prestandard Section 5.5.2.3.2, Item 5 has been revised to reference Section 1913 of the IBC for calculation of anchor bolt strength, using ϕ equal to 1.0. Anchor bolt failure modes governed by concrete are designated as force-controlled actions.

5-12 **Braced Frame Connection Requirements Need Clarification**

Braced frame connection provisions appear too restrictive for applications where braces are lightly loaded and the connections are required to develop brace capacities that will not be utilized. Provisions are difficult to understand and should be clarified.

Section: 5.5 (new Section 5.6).

Classification: *Technical Revision.*

Discussion: The original *Guidelines* required that connections develop 1.25 times the compression capacity of the brace, or the brace *m*-factors were to be reduced by one half. This requirement is inconsistent with the overall methodology of force- and deformation-controlled actions. Brace connections should be treated as force-controlled and brace *m*-factors should not be related to connection capacity.

Resolution: Prestandard Section 5.6.2.4 has been revised to delete this requirement on brace connection capacity and associated adjustment in brace *m*-factors. Additionally, brace connection demands have been clearly defined as force-controlled actions.

5-13 **Incorporate SAC Research Into Chapter 5**

The acceptance criteria for steel moment resisting frame components in Chapter 5 should be updated to reflect the results of SAC research.

Section: 5.4 (new Section 5.5)

Classification: *Application of Published Research.*

Discussion: Special Study 9 – Incorporating Results of the SAC Joint Venture Steel Moment Frame Project was funded to research this issue. This study reviewed results of SAC research, and translated test results and reliability studies into plastic hinge rotation limits for FR and PR moment frame connections that are consistent with the format of acceptance criteria in other chapters.

Resolution: Section 5.5, Table 5-4, and Table 5-5 in the Prestandard have been revised to incorporate SAC research results.

5-14 **Steel Acceptance Criteria is Based on Component Length**

Nonlinear acceptance criteria for certain steel components are expressed as a multiple of yield rotation, which is based on the length of the component.

Section: 5.4, 5.5

Classification: *Recommended for Basic Research*

Discussion: Related to issue 5-8 regarding inconsistent specification of acceptance criteria. Values in Table 5-6 have been revised to express acceptance criteria in terms of plastic rotations as a multiple of yield rotation to be more consistent with other chapters. This however, has not changed the fundamental basis of the acceptance criteria for steel components. Calculation of yield rotation is based on chord rotation, and is proportional to the length of the component. This means that as the length of the component increases, the permissible plastic deformation increases. This is inconsistent with plastic rotation limits for concrete moment frames specified in Chapter 6, that are independent of component length. It is not immediately obvious why a given steel section would have a different plastic rotation limit when used in a component of a different length. In addition, as the length of the member decreases, the permissible plastic rotation tends toward zero.

Resolution: Unresolved pending future research.

5-15 **The Ratio Between IO and LS Acceptance Criteria Appears Too Large**

The ratio between IO and LS acceptance criteria for certain steel components appears to be too large. IO values for these components appear to be too low.

Section: 5.4, 5.5, 5.6 (new Tables 5-5 and 5-6)

Classification: *Recommended for Basic Research*

Discussion: Special Study 6, Acceptability Criteria (Anomalous m-values), identified this issue. One conclusion of this study was that based on Section 2.13 (Prestandard Section 2.8) Immediate Occupancy acceptance criteria should be on the order of 25% to 50% of the values for Life Safety. Values for diagonal brace, steel plate shear wall, and diaphragm components exceed these ratios.

Resolution: Unresolved pending future research.

5-16 **Nonlinearity is Permitted in Column Base Plates**

For certain controlling actions, nonlinearity is permitted in column base plates. Column bases should be treated as force-controlled.

Section: 5.4.2.3, 5.4.3.3 (new Section 5.5.2.3.2, Item 5)

Classification: *Recommended for Basic Research*

Discussion: This issue was raised at the 8/23/00 Standards Committee meeting. Exception was taken to the use of m-factors on column base connections. It was stated that nonlinearity should be forced to occur in the structure above the base connection. This is contrary to the original intent of the *Guidelines*, which permitted nonlinear activity on ductile behavior such as the base plate yielding.

Resolution: Unresolved pending future research.

5-17 **Tension-only Braces Have Full Nonlinear Deformation Limits**

Tension-only braces have the same nonlinear deformation limits as tension/compression braces.

Section: 5.5 (new Section 5.6)

Classification: *Technical Revision*

Discussion: The behavior of tension-only bracing systems is very different than systems in which the braces act in both tension and compression. Tension-only systems have extremely pinched hysteretic behavior and are subject to impact loading as the braces alternately stretch, buckle and then re-tension. Linear acceptance criteria (*m*-factors) for these systems are adjusted to half the values for tension/compression braces, but no such adjustment is provided for nonlinear acceptance criteria.

Resolution: A footnote has been added to Prestandard Table 5-6 to reduce nonlinear deformation limits by one-half for tension-only brace components, similar to the original note applying to *m*-factors.

6. Concrete
(Systematic Rehabilitation)

Chapter 6 provides guidance on systematic rehabilitation of concrete structural systems including moment frames, braced frames, shear walls, diaphragms and foundations. It includes procedures for obtaining material properties and the condition assessment of concrete structures, and describes the acceptance criteria for concrete components.

6.1 New Concepts

- Testing requirements: The *Guidelines* include new requirements on testing and condition assessment for determination of design and analysis parameters for the concrete structure.
- Non-conforming components and elements: Procedures are included for quantitatively evaluating the capacity of elements and components that may have limited ductility because they do not conform to the reinforcing requirements of modern day codes, standards or construction.
- Modeling parameters: Specific guidance is provided on modeling parameters for concrete elements including effective stiffness, and material properties.
- Flanged construction: Intersecting components will act compositely, and the response will differ substantially from that of isolated components. Specific guidance is provided for assigning a portion of perpendicular intersecting components as effective flanges for the component under consideration.
- Rehabilitation techniques: Specific guidance is provided on selecting appropriate rehabilitation techniques for concrete systems. Among traditional measures including addition of shear walls or shotcrete elements to the structural system, rehabilitation techniques include jacketing non-conforming elements to improve confinement.
- Infill frames: The *Guidelines* include enhanced discussion of the interaction between infill walls and frame elements, and new evaluation techniques for rehabilitation of infill frame systems.

6.2 Global Issues

6-1 *m*-factors Appear Overly Conservative

Certain values of acceptance criteria (*m*-factors) and deformation limits for concrete components appear to be too conservative and are not consistent with other chapters. Of particular concern is an inconsistency with Chapter 7, Masonry.

Section: Tables 6-6, 6-7, 6-8, 6-10, 6-11, 6-12, 6-13, 6-14, 6-15, 6-16, 6-17, 6-18, 6-19, 6-20; Sections 6.5.x.4, 6.6.x.4, 6.7.x.4, 6.8.x.4, 6.9.2.4, 6.10.5, 6.11.2, 6.12.2, 6.13.3.

Classification: *Recommended for Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to augment data used to develop acceptance criteria. Existing values were determined on a rational basis using available experimental results. This issue is related to issue 2-6 regarding baselining of acceptance criteria. Special Study 6 – Acceptability Criteria (Anomalous *m*-values) was funded to research this issue. The results of this study are still under consideration by the Project Team. Changes to *m*-factor tables in Chapter 6 are on hold pending further discussion.

Resolution: Unresolved pending future research.

6-2 Presentation by System Type is Redundant

The presentation of material evaluation and acceptance criteria by system type, such as moment frame, shear wall, etc. is redundant, difficult to follow, and makes it difficult to compare the criteria for each system.

Section: 6.5, 6.6, 6.7, 6.8, 6.9, 6.10, 6.11, 6.12, 6.13.

Classification: *Non-persuasive.*

Discussion: This change would require editorial reorganization of information in all materials chapters. At the 3/3/99 Standards Committee meeting this issue was reclassified as non-persuasive.

Resolution: No change proposed.

6-3 Too Much Testing is Required

The *Guidelines* require too much testing of in-place materials for the determination of design and analysis parameters.

Section: 6.3.2, 6.3.3.

Classification: *Technical and Commentary Revision (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to develop non-destructive test and inspection procedures for in-situ evaluation of materials. This issue is related to issues 2-18 and 5-4 regarding knowledge factor and too much required testing of steel. Acceptance criteria depend on reliable knowledge of the material properties and condition of the components. Nonlinear procedures in particular require an in-depth understanding of the condition and material properties of components. Testing and condition assessment decreases the potential uncertainty and increases the reliability of results. However, the level of testing and destructive condition assessment specified in the *Guidelines* is extreme, and far in excess of standard practice. The amount of required testing is related to the selected analysis procedure, the level of information available on the building and the knowledge factor used in the analysis.

Resolution: Prestandard Section 2.2.6 was created to clearly outline data collection requirements. Minimum, comprehensive, and a new classification called usual data collection have been clearly defined. New provisions for usual data collection in Prestandard Sections 5.3.2 and 5.3.3 are intended to match current standard practice with regard to testing and condition assessment. Original FEMA 273 materials testing and destructive condition assessment provisions have been assigned to comprehensive data collection. New Table 2-1 was created to provide a matrix of information used for determination of testing requirements as related to rehabilitation objective, analysis procedure and knowledge factor.

6-4 Guidance for Concrete Infill Panels Needed

The section on infill frames does not provide guidance on evaluation of concrete infill panels.

Section: 6.7.

Classification: *Commentary Revision.*

Discussion: At the 3/3/99 Standards Committee meeting this issue was reclassified as a commentary revision.

Resolution: Commentary to Prestandard Section 6.7.1.3 has been added to provide additional guidance on concrete infill.

6-5 **Inconsistent Definition of Weak Story**

Definition of weak story in Section 6.5.2.4 is not consistent with the definition in Section 2.9.1.1. DCR requirements should be centralized in one location with additional explanation regarding their use.

Section: 6.5.2.4, 2.9.1.1 (new section 2.4.1.1).

Classification: *Technical Revision.*

Discussion: Section 2.9.1.1 is a trigger measuring relative story strengths. Section 6.5.2.4 is a trigger measuring relative strengths of beams and columns. Section 6.5.2.4 should refer to weak column elements, so there is no conflict in definitions. Material specific DCR requirements are best located in the appropriate materials chapter. Proposed changes regarding DCRs were found non-persuasive by the Prestandard Project Team.

Resolution: Prestandard Section 6.5.2.4.1 has been revised to refer to weak column elements.

6-6 **Clarify Shear Wall Component Definitions**

Clarification is required regarding evaluation of pierced shear walls. Classification of components as wall segments, beams or coupling beams needs further guidance. The acceptance criteria are not consistent between classifications.

Section: 6.8.2.

Classification: *Application of Published Research.*

Discussion: It is not clear how to select the most appropriate classification for components of pierced shear walls. Acceptance criteria in terms of plastic hinge rotation are more stringent for wall segments than they are for non-ductile concrete frame elements, which seems inconsistent with expected performance of the two systems. Special Study 8 – Incorporation of Selected Portions of Recent Related Documents was funded to research this issue. The main conclusion of this study was that useful information is available in FEMA 306, 307 and 308, to assist in classifying and evaluating the concrete components, but since these documents are not standards themselves, they could not be referenced directly by the Prestandard.

Resolution: Information consisting of a table of component types and figure showing various wall component configurations has been extracted from FEMA 306 and added as new commentary to Prestandard Section 6.8.1 to assist in the identification of wall component classifications.

6-7 ***m*-factors Less Than 1.0 Too Low**

Component modification factors (*m*-factors) less than 1.0 imply certain concrete components require strengths in excess of pseudo lateral force elastic demands, which does not make sense.

Section: All.

Classification: *Technical Revision.*

Discussion: No *m*-values less than 1.0 appear in Chapter 6.

Resolution: No change proposed.

6-8 **Tables 6-13 and 6-14 Reversed**

Tables 6-13 and 6-14 regarding *m*-values and deformation acceptance criteria for flat plate moment frames are interchanged and incorrectly referenced within the text.

Section: Tables 6-13 and 6-14; Section 6.5.4.4.

Classification: *Editorial Revision.*

Discussion: None.

Resolution: The Prestandard has been corrected to properly reference the tables.

6-9 ***m*-factors Less Than 2.0 Worse Than Force-Controlled**

Considering actions associated with *m*-factors less than 2.0 as deformation-controlled may be more restrictive than considering the same action as force-controlled and using the J factor.

Section: 3.4.2.

Classification: *Commentary Revision.*

Discussion: J can be between 1.0 and 2.0. Force-controlled actions are less desirable than deformation-controlled actions, and the criteria should be more restrictive. When *m* is less than about 1.5 it may appear to be more favorable to treat elements as forced-controlled. However, calculation of demand on force-controlled actions requires a limit state analysis, and capacity is calculated using lower bound strengths. If these concepts are properly applied, the method will yield a safe result whether the action is considered force- or deformation-controlled.

Resolution: Commentary from FEMA 274, Section 3.4.2.1 has been added to Prestandard Section 3.4.2.1.2 to clarify the application of force-controlled acceptance criteria.

6-10 **Column Acceptance Criteria Overly Conservative**

The acceptance criteria for concrete columns appear to be overly conservative, even for secondary elements. Concrete shear strength goes to zero at high ductility demands, which may too stringent.

Section: Table 6-7, 6-11 (new Tables 6-8, 6-12); Sections 6.4.4, 6.5.

Classification: *Technical Revision.*

Discussion: Special Study 5 – Report on Multidirectional Effects and P-M Interaction on Columns was funded to research this issue. The major conclusion of this study was that more data on concrete column failures in the range of interest is available, and revisions of the acceptance criteria can be made.

Resolution: Column acceptance criteria in Prestandard Section 6.5.2.3.1 have been revised in accordance with this study. Prestandard equation 6-4 for concrete contribution to shear capacity has been revised to better match results from tests. Prestandard Tables 6-8 and 6-12 have been revised to increase acceptance criteria for concrete columns based on data from recent tests.

6-11 **Footnote 1, Table 6-20 Incorrect**

Footnote 1 in Table 6-20 incorrectly reads ‘stress’ when it should read ‘capacity’.

Section: Table 6-20 (new Table 6-21).

Classification: *Non-persuasive.*

Discussion: Footnote 1 sets limits on application of deformation acceptance criteria based on axial load and shear demands on the element. The term ‘capacity’ is not appropriate.

Resolution: Prestandard Table 6-21 has been revised to read ‘demand’ in Footnote 1.

6-12 **Table 6-17 Missing Headings**

Table 6-17 regarding numerical acceptance criteria for nonlinear procedures is missing column headings. Rotation limits for coupling beams should be entitled chord rotations.

Section: Table 6-17.

Classification: *Editorial Revision.*

Discussion: The missing headings imply the acceptance criteria listed for coupling beams are plastic hinge rotation limits. This is incorrect and significantly different from the correct limits which are actually chord rotation limits.

Resolution: Column headings in Prestandard Tables have been corrected.

6-13 **Column P-M Interaction Unclear**

Acceptance criteria for P-M interaction in concrete columns is unclear.

Section: 6.4.3.

Classification: *Technical Revision.*

Discussion: This issue was raised at the 3/3/99 Standards Committee meeting. Flexure in concrete columns is treated as deformation-controlled, while axial loads are force-controlled. For concrete braced frames in Section 6.10.5, axial actions in braces are considered deformation controlled. It is unclear how to check the interaction between force-controlled and deformation-controlled actions when they occur simultaneously on one component. Special Study 5 – Report on Multidirectional Effects and P-M Interaction on Columns was funded to research this issue.

Resolution: Prestandard Section 6.4.3 has been expanded to provide direction on how to address P-M interaction and biaxial bending of concrete columns. Axial force actions are considered force-controlled and a squared interaction relationship for biaxial bending has been introduced.

6-14 **Guidance for Lightweight Concrete Needed**

Guidance is required on how to address lightweight concrete in capacity calculations.

Section: Chapter 6, all.

Classification: *Technical Revision.*

Discussion: The current document refers to ACI 318 for calculation of component strengths. Since ACI 318 addresses lightweight concrete, it can be interpreted that consideration of lightweight concrete has already been included. However, this consideration could be made more explicit.

Resolution: Prestandard Sections 6.4.2.2 and 6.4.2.3 have been revised to explicitly reference ACI 318 adjustments for lightweight concrete in the calculation of component strengths.

6-15 **Guidance for Square Rebar Needed**

Guidance is required on how to address square reinforcing steel in capacity calculations.

Section: Chapter 6, all.

Classification: *Technical Revision.*

Discussion: None.

Resolution: Prestandard Section 6.4.5.1, Square Reinforcing Steel, has been created to provide direction on square bars. Twisted square bars are to be treated as deformed bars and straight square bars are to be treated as plain bars. For calculation of required development length or maximum developed stress in square reinforcing bars (Prestandard Section 6.4.5), the area of the square bars, or an effective bar diameter, d_b, calculated based on the area of the square bars, will be used as appropriate.

6-16 ***m*-factors for Concrete Diaphragms Needed**

Acceptance criteria for concrete diaphragms are based on DCR values. Diaphragm criteria should be base on *m*-factors.

Section: 6.11, 6.11.2.4.

Classification: *Technical Revision.*

Discussion: Cast-in-place concrete diaphragm components can be considered to behave like shear wall components. The current criteria using DCR values is overconservative.

Resolution: Prestandard Section 6.11.2.4 on concrete diaphragms has been revised to reference acceptance criteria for shear walls. Section 6.12.2 has been revised to incorporate conservative *m*-factors, based on judgement, for topping slabs on precast concrete diaphragms

6-17 **Acceptability for Columns in Tension Missing**

Acceptability requirements for concrete columns in tension are not provided.

Section: 6.4.

Classification: *Recommended for Basic Research.*

Discussion: None.

Resolution: Unresolved pending future research.

6-18 **Calculation of M_y for Shearwalls Unconservative**

The procedure in Section 6.8.2.3 for calculating the yield moment of reinforced concrete wall sections may underestimate the actual flexural capacity. This result would be unconservative for use in a limit state analysis.

Section: 6.8.2.3.

Classification: *Recommended for Basic Research*

Discussion: None.

Resolution: Unresolved pending future research.

6-19 **Omit Sampling of Prestressing Steel**

Sampling of prestressing steel is unnecessary and dangerous. Requirements for testing of prestressing steel should be deleted.

Section: 6.3.2.4 (new Section 6.3.2.4.4).

Classification: *Non-persuasive*

Discussion: Prestandard Section 6.3.2.4.4 currently only calls for sampling of prestressing steel for lateral force resisting elements, and suggests that sampling should occur beyond the anchorage to avoid loss of prestress. If a prestressed component is going to be used for lateral force resistance in the rehabilitated structure, the material properties of the prestressing steel must be subject to the same data collection requirements of other materials. For linear procedures, BSO performance, and minimum or usual data collection with information from drawings, testing would not be required. However, for enhanced objectives, or in the absence of drawings, testing would be necessary.

Resolution: No change made.

6-20 **Concrete Flange Provisions Unconservative**

Provisions for flanged sections in Section 6.4.1.3 may underestimate the frame action of the system when applied to joist construction.

Section: 6.4.1.3.

Classification: *Recommended for Basic Research.*

Discussion: None.

Resolution: Unresolved pending future research.

6-21 **Clarify Definition of Closed Stirrups, Ties and Hoops**

The terms closed stirrups, ties and hoops are not used consistently in tables of concrete acceptance criteria.

Section: Tables 6-7, 6-8, 6-9, 6-18, Section 6.14

Classification: *Technical Revision.*

Discussion: Table 6-7 for beams reads closed stirrups at hinge locations. Table 6-8 for columns reads closed hoops at hinge locations. Table 6-9 for joints reads closed hoops with 135 degree hooks and no lap splices within the joint. Table 6-18 for wall segments reads closed stirrups along entire length. Since these terms are important for selection of appropriate acceptance criteria, clarification is needed regarding the necessity for 135 degree hooks and absence of lap splices.. The intent of the original FEMA 273 *Guidelines* was that, in the case of beam, column and joint components of concrete moment frames, conforming transverse reinforcement meant ACI hoops with no lap splices and 135 degree hooks on the ends (with 90 degree hooks permitted on cross-ties). This requirement was not intended to apply to concrete wall segments.

Resolution: The terms “hoops” and “closed ties or stirrups” have been added to the list of definitions in the Prestandard. “Hoops” refers to ACI 318 hoops, with seismic hooks and no lap splices. “Closed ties or stirrups” refers to ACI 318, Section 7.11 for lateral reinforcement of flexural members, which permits 90 degree hooks and lap splices. The footnotes of tables 6-7, 6-8 and 6-9 for concrete frame components have been revised to refer to hoops as defined above. The footnotes of Table 6-18 for shear wall components have been revised to refer to closed ties or stirrups.

7. Masonry
(Systematic Rehabilitation)

Chapter 7 provides guidance on systematic rehabilitation of masonry structural systems including shear walls, infill walls, wall anchorage and foundations. Types of masonry covered by this chapter include solid or hollow clay-unit masonry, solid or hollow concrete-unit masonry and hollow clay tile, but excludes glass block and stone masonry. It includes procedures for obtaining material properties and the condition assessment of masonry elements, and describes the acceptance criteria for masonry components.

7.1 New Concepts

- Testing requirements: The *Guidelines* include new requirements on testing and condition assessment for determination of design and analysis parameters for masonry components.
- Rehabilitation techniques: Specific guidance is provided on selecting appropriate rehabilitation techniques for masonry elements. Techniques include infilling openings, enlarging openings, applying shotcrete or other exterior structural bracing.
- Infill walls: The *Guidelines* include enhanced discussion of the interaction between infill walls and frame elements, and new evaluation techniques for rehabilitation of masonry infill wall components.
- Ductility in URM walls: The evaluation of unreinforced masonry walls now considers two new failure modes consisting of bed-joint sliding shear and toe crushing that are defined and quantified. Depending on which failure mode governs the behavior, the walls can be considered deformation-controlled, and *m*-values are provided.

7.2 Global Issues

7-1 *m*-factors Appear Overly Conservative

Certain values of acceptance criteria (*m*-factors) and deformation limits for masonry components appear to be too conservative and are not consistent with other chapters. Of particular concern is an inconsistency with Chapter 6, Concrete.

Section: Tables 7-1, 7-4; Sections 7.4.2.3, 7.4.4.3, 7.5.2.3, 7.7.2.

Classification: *Recommended for Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to augment data used to develop acceptance criteria. Additional studies of inelastic behavior of elements are recommended to refine acceptance criteria. Acceptance criteria for masonry elements appear to result in higher capacities than similar elements in concrete, which is counter-intuitive. This issue is related to issue 2-6 regarding baselining of acceptance criteria. Special Study 6 – Acceptability Criteria (Anomalous *m*-values) and Special Study 10 – Issues related to Chapter 7 were funded to research this issue further. The conclusions of Special Study 6 did not impact *m*-factor tables in Chapter 7. Special Study 10 concluded that *m*-factors for shear controlled reinforced masonry walls were necessary to make Chapter 7 more consistent with Chapter 6. These factors were subsequently incorporated into Prestandard Tables 7-6 and 7-7, but neither study concluded that significant changes to the remaining *m*-factors were required.

Resolution: Unresolved pending future research.

7-2 URM h/t Limits Independent of Performance Level

Height to thickness ratio acceptance criteria for URM walls out-of-plane does not change for CP, LS, and IO performance levels.

Section: Tables 7-3; Section 7.4.3.3.

Classification: *Non-persuasive.*

Discussion: Height to thickness ratios are not applicable to the IO performance level. Meeting the ratios satisfies the LS performance level, but there is no technical basis for relaxing the criteria for the CP performance level.

Resolution: No change proposed.

7-3 Interpolation Not Specified

Not all acceptance values are defined as a “sliding scale” between limits.

Section: All Tables, 7.4.4.2.

Classification: *Editorial Revision.*

Discussion: All tables note that interpolation between values is permitted. In Section 7.4.4.2, it is not clear that for values of M/Vd between limits for equations 7-9 and 7-10, interpolation is intended.

Resolution: Prestandard Section 7.4.4.2.2 has been revised to specify interpolation between limits.

7-4 Guidance for Infill Panels with Openings Needed

Evaluation of masonry infills does not provide adequate guidance for addressing masonry infill panels with openings.

Section: 7.5.2.

Classification: *Commentary Revision and Basic Research.*

Discussion: At the 3/3/99 Standards Committee meeting this issue was reclassified as a commentary revision. While the equivalent diagonal compression strut analogy may not be directly applicable when openings are present in the infill panel, some guidance is provided on how to modify the procedure when openings are present. Further research is necessary to develop simplified methods for considering openings in infill panels.

Resolution: Additional information from FEMA 274 was added to the commentary for Prestandard Section 7.5.2. Further resolution of this issue is recommended for basic research.

7-5 Quantitative Definition of Masonry Terms Needed

The acceptance criteria for masonry components in Chapter 7 depend on the condition of the masonry. Qualitative terms such as good, fair, poor, significant cracking, etc. are used throughout. A quantitative measure or definition of these terms is required to properly apply the provisions of the standard.

Section: 7.3.2.1, 7.8.

Classification: *Application of Published Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to establish an improved relationship between crack widths and performance of damaged masonry components. For the standard to be enforceable, qualitative terms must be defined with some quantitative measurement. The ATC-43 project (FEMA 306, 307 and 308) is a potential source for information on crack widths. Special Study 8 - Incorporation of Selected Portions of Recent Related Documents was funded to research this issue. The main conclusion of this study was that useful information is available in FEMA 306, 307 and 308, to assist in evaluating the condition of masonry, but since these documents are not standards themselves, they could not be referenced directly by the Prestandard.

Resolution: Commentary was added in Prestandard Section 7.3.2.1, and in the definitions of Section 7.8, to reference more detailed information on the condition of masonry contained in FEMA 306, 307 and 308.

7-6 **1.25 fy Not Specified for Masonry**

Expected strength calculations for reinforced masonry components do not utilize 1.25*fy for strength of reinforcement, similar to concrete components.

Section: 7.3.2.10, 7.4, 7.4.4.2.1

Classification: *Commentary Revision.*

Discussion: Calculation of expected strength of masonry components calls for the use of expected material properties. The expected strength of reinforcing steel is intended to include consideration of material overstrength and strain hardening expected in yielding components. Section 7.3.2.10 on default properties references Chapter 6 for reinforcing steel, which includes a 1.25 factor used to convert lower bound yield stress to expected strength. Section 7.4 was previously revised to include reference to using 1.25*nominal yield stress, but this is redundant with the use of expected strength.

Resolution: Commentary has been added to Prestandard Sections 6.4.2.2, and Section 7.4 to clarify that the use of expected strength material properties for reinforcing steel includes a 1.25 factor to account for material overstrength and strain hardening that is expected in yielding components.

7-7 **h/t Ratios for S_{X1} Exceeding 0.5g Needed**

The spectral response acceleration values in the headings of Table 7-3 for URM h/t ratios are limited to 0.50g. There is no guidance for sites with S_{X1} values exceeding 0.50g.

Section: Section 7.4.3.3, Table 7-3 (new Table 7-5).

Classification: *Technical Revision.*

Discussion: The h/t ratios in Table 7-3 were developed with a different definition of seismic hazard in mind. Values for S_{X1} between 0.37g and 0.50g are applicable above 0.50g.

Resolution: Table 7-5 in the Prestandard has been revised so that the column of h/t ratios for the highest seismic hazard is not limited to 0.50g.

7-8 **Clarify Application of Equations 7-5 and 7-6**

The application of Equations 7-5 and 7-6, particularly outside of specified L/h_{eff} limits, is unclear.

Section: Section 7.4.2.2.

Classification: *Editorial Revision.*

Discussion: None.

Resolution: Prestandard Sections 7.4.2.2 and 7.4.2.2.2 have been expanded to clarify the proper application of Equations 7-5 and 7-6.

7-9 **Clarify Definition of Effective Height**

The definitions of parameters Δ_{eff} and h_{eff} require additional clarification.

Section: Section 7.9, 7.4.2.3.2 (related to Figure 7-1)

Classification: *Commentary Revision.*

Discussion: This issue was raised in the BSSC Case Studies Report and Special Study 1 - Early Input from the BSSC Case Studies Report was funded to research this issue further.

Resolution: Prestandard definitions of parameters Δ_{eff} and h_{eff} have been clarified. Commentary to Prestandard Section 7.4.2.3.2 has been added with a figure to clarify what is meant by these terms.

7-10 **Masonry Shear Strength Based on Average Test Values is Unconservative**

The calculation of expected masonry shear strength using average values of brick shear tests overestimates the actual shear strength.

Section: 7.3.2.4

Classification: *Application of Published Research*

Discussion: This issue was raised at the 8/23/00 Standards Committee meeting. Use of average shear test values to estimate shear strength by calculation reportedly does not correlate well with results of full-scale wall tests. Special Study 10 – Issues related to Chapter 7 was funded to research this issue further. This study concluded that average brick shear test values was the intended value, although this resolution has not found consensus with all members of the standards committee.

Resolution: Unresolved pending further study.

7-11 **URM Shear Strength Should be Force-Controlled**

Shear strength of URM walls is brittle and unreliable and should be treated as a force-controlled action.

Section: 7.4.2.2

Classification: *Recommended for Basic Research*

Discussion: This issue was raised at the 8/23/00 Standards Committee meeting. The shear strength of URM walls is limited by diagonal tension failure that that originates at the weakest point in the brick and mortar matrix. Shear failure is brittle and the ultimate values are unreliable. This type of action should not have *m*-factors that permit significant inelastic activity. This is contrary to the concept introduced in the original *Guidelines* that URM walls governed by bed-joint sliding or rocking have some level of ductility. Special Study 10 – Issues related to Chapter 7 was funded to research this issue further. This study concluded that certain shear failures in URM walls could be considered deformation-controlled, although this resolution has not found consensus with all members of the standards committee.

Resolution: Unresolved pending future research.

8. Wood and Light Metal Framing
(Systematic Rehabilitation)

Chapter 8 provides guidance on systematic rehabilitation of wood and light metal framing systems including shear walls, diaphragms and foundations. It includes procedures for obtaining material properties and performing the condition assessment, and describes the acceptance criteria for wood and light metal framing components.

8.1 New Concepts

- Testing requirements: The *Guidelines* include new requirements on testing and condition assessment for determination of design and analysis parameters for wood and light metal framing components.
- Rehabilitation techniques: Specific guidance on selecting appropriate rehabilitation techniques for wood and light metal framing elements is provided. Techniques include the addition of wood structural panel overlays on existing assemblies, and increased attachment between sheathing and framing.
- Strength varies with aspect ratio: Because excessive deflection can result in major damage to the structure and its contents, acceptance criteria for wood components is based on the height/length or length/width ratios.
- Non-conforming components and elements: Procedures are included for quantitatively evaluating the capacity of elements and components that do not conform to construction based on modern day codes and standards.

8.2 Global Issues

8-1 ***m*-factors Appear Overly Conservative**

Certain values of acceptance criteria (*m*-factors) and deformation limits for wood components appear to be too conservative.

Section: Table 8-1.

Classification: *Recommended for Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to augment data used to develop acceptance criteria. Additional studies of inelastic behavior of elements are recommended to refine acceptance criteria. This issue is related to issue 2-6 regarding baselining of acceptance criteria. Special Study 6 – Acceptability Criteria (Anomalous *m*-values) and Special Study 11 – Wood Issues were funded to research this issue further. The conclusions of Special Study 6 did not impact *m*-factor tables in Chapters 8, however, Special Study 11 concluded that, based on current available research, tabulated *m*-factors appear to be appropriate given the expected strengths provided.

Resolution: Unresolved pending future research.

8-2 **Guidance for Diaphragm Chord Area Needed**

More guidance on how to determine the area of the chord for use in a diaphragm deflection calculation is required.

Section: 8.5.7.1.

Classification: *Commentary Revision.*

Discussion: Chapter 8 covers acceptance criteria for wood diaphragms that is applicable to all building types with wood diaphragms. The area of the chord can be different on each side particularly when concrete walls are present and only the reinforcing steel can be considered effective in tension. Further clarification is required on what to consider as diaphragm chords.

Resolution: Commentary to Section 8.5.7.1 has been added in the Prestandard to provide additional guidance.

8-3 **Wood Values Based on Judgment**

Values for wood components are based on engineering judgment rather than tests.

Section: All.

Classification: *Recommended for Basic Research.*

Discussion: Special Study 11 – Wood Issues was funded to research this issue further. This study reviewed historic research as well as preliminary results from current research underway at UCI, and proposed revisions to tabulated strength and stiffness values for wood shear wall and diaphragm assemblies.

Resolution: Revised tabulated strength and stiffness values for wood shear wall and diaphragm assemblies, and revised equations for calculation of shear wall and diaphragm deflections have been incorporated into Prestandard Chapter 8.

8-4 **Anomalous *m*-factors for Different Assemblies**

There are apparent anomalies when *m*-values for different assemblies are compared.

Section: Table 8-1.

Classification: *Commentary Revision.*

Discussion: As an example, *m*-values for gypsum plaster are higher than values for structural panels, implying better performance. However, since expected strengths for gypsum plaster are much lower than structural panels, the combination of *m**Qce is higher for structural panels, as expected. There is no real anomaly.

Resolution: Commentary has been added to the Prestandard to explain this apparent anomaly.

8-5 **Combined with 3-8**

Combined with Global Issue 3-8 and omitted.

Section: None.

Classification: *None.*

Discussion: None.

Resolution: None.

8-6 Use of Default Values Needs Clarification

The shear wall and diaphragm sections list capacities and non-linear parameters for various assemblies. It is not clear whether these values are directly applicable to the NSP, or if verification testing is required before the specified nonlinear parameters can be used.

Section: 8.3.2.5.

Classification: *Editorial Revision.*

Discussion: Capacity values and nonlinear acceptance criteria in Chapter 8 are similar in concept to acceptance criteria specified for other materials. These values are intended to be used directly, without verification testing of mock-up assemblies.

Resolution: Prestandard Section 8.3.2.5 has been revised to clarify the use of default capacities for assemblies. Section 8.3.4 has been revised to make knowledge factor, κ, requirements consistent with this intent.

8-7 Inconsistent Requirements for Connections

The sections on various types of shear wall assemblies require connections to be checked or not checked depending on the perceived strength of the assembly. The sections are not consistent. In some cases weaker assemblies require verification of connections, and stronger assemblies do not.

Section: 8.4.x.4.

Classification: *Technical Revision.*

Discussion: For example, Section 8.4.11 for plaster on wood lath lists a capacity of 400 lbs/ft and does not require the connections to be checked, while Section 8.4.4 for horizontal siding lists a capacity of 80 lbs/ft and requires connections to be checked. The original distinction between assemblies requiring verification of connections and those that did not was related to ease of inspection and ability to verify connections without destroying the assembly.

Resolution: Prestandard Sections 8.4.x.4 have been revised for consistency with regard to verification of connections.

8-8 Guidance on Wood Components in Compression Needed

Guidance on the evaluation of wood posts below discontinuous shear walls, components of knee-braced frames, and braced horizontal diaphragms is needed.

Section: 8.4.

Classification: *Technical Revision.*

Discussion: Wood components are generally considered deformation-controlled. Provisions on how to address wood components in compression are necessary because this situation requires a force-controlled application of the criteria.

Resolution: Prestandard Section 8.4 has been revised to provide direction on consideration of posts below discontinuous shear walls. Prestandard Section 8.8 was created to provide direction on strength and acceptance criteria for knee-braced frames and other miscellaneous wood components.

8-9 **Lower-Bound Capacities for Wood Components Needed**

Direction on calculation of lower-bound capacities for wood components is needed for evaluation of force-controlled actions.

Section: 8.3.2.5

Classification: *Technical Revision.*

Discussion: Wood components and connections are generally considered deformation-controlled. Because of this, Chapter 8 lacks defined criteria for calculation of lower-bound capacities. These capacities are needed for evaluation of force-controlled actions on wall anchorage components, bodies of connections, posts below shear walls. Special Study 11 – Wood Issues was funded to research this issue further. The factor proposed in this study (0.85) is based on mean minus one standard deviation values for the recently completed CoLA/UCI testing of shear walls.

Resolution: Prestandard Section 8.3.2.5 has been revised to include a 0.85 factor for conversion from expected strength to lower bound for use when needed.

8-10 **Stiffness Values for Wood Assemblies are Not Supported by Tests**

Stiffness values that are provided for wood shear wall and diaphragm assemblies are inconsistent and not supported by tests.

Section: 8.3.2.5, 8.4, 8.5 (new Tables 8-1 and 8-2)

Classification: *Application of Published Research*

Discussion: This issue was raised at the 8/23/00 Standards Committee meeting. Values for assemblies when used as shear walls are different for the same assemblies when used as diaphragms. Special Study 11 – Wood Issues was funded to research this issue further. This study reviewed preliminary results from the recently completed CoLA/UCI testing of shear walls to develop proposed revisions to tabulated shear wall and diaphragm assembly stiffness.

Resolution: Revised tabulated stiffness values for wood shear wall and diaphragm assemblies, and revised equations for calculation of shear wall and diaphragm deflections have been incorporated into Prestandard Chapter 8.

8-11 **Wood Conversion Factors are not Supported by Tests**

Factors used to convert allowable values to expected strength are not supported by tests.

Section: 8.3.2.5

Classification: *Application of Published Research*

Discussion: This issue was raised at the 8/23/00 Standards Committee meeting. Factors consisting of 2.16*0.8*1.6=2.8 are not representative of the actual factors of safety present between allowable values of wood components and tested ultimate strengths. Special Study 11 – Wood Issues was funded to research this issue further. This study reviewed preliminary results from the recently completed CoLA/UCI testing of shear walls to develop revised conversion factors based on the test results

Resolution: The methodology for calculating component capacities has been revised to a strength-based procedure using wood LRFD provisions. Revised conversion factors from allowable to expected strength have been provided in the commentary to retain this method as an alternative.

9. Seismic Isolation and Energy Dissipation (Systematic Rehabilitation)

Chapter 9 provides guidance on systematic rehabilitation of buildings using base isolation or passive energy dissipation systems. It includes specific direction on both linear and nonlinear modeling and analysis procedures for structures with isolators or energy dissipation devices. It also includes requirements for verification and testing of the design properties of isolators and energy dissipation devices.

9.1 New Concepts

Passive energy dissipation systems: The *Guidelines* provide direction on the implementation of energy dissipation devices in the systematic rehabilitation of structures. While design provisions for seismic isolation have been in place for some time, comprehensive provisions for energy dissipation have not been published before the *Guidelines*.

9.2 Global Issues

9-1 **Procedures Require Validation**

Analytical procedures for energy dissipation systems require validation.

Section: 9.3.

Classification: *Recommended for Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to validate energy dissipation procedures through analytical studies comparing results of linear static and nonlinear static analyses with results of nonlinear time-history analyses.

Resolution: Unresolved pending future research.

9-2 **Inconsistent Nomenclature**

Response acceleration parameter nomenclature in Chapter 9 is not consistent with the nomenclature in the rest of the document.

Section: 9.2, 9.3, 2.6.1.5.

Classification: *Editorial Revision.*

Discussion: The names of the spectral response acceleration parameter variables in Chapter 9 are different from those elsewhere in the document. Section 2.6.1.5 includes a cross-reference between the variables.

Resolution: The nomenclature in Chapter 9 of the Prestandard has been revised to be consistent with the rest of the document. Section 2.6.1.5, which previously provided cross-reference information for the nomenclature has been deleted.

9-3 **Clarify Use of C1, C2, C3 with Isolation**

Clarification regarding the use of coefficients C_1, C_2 , C_3 , and J for seismically isolated structures is required in Chapter 9.

Section: 9.2.1.

Classification: *Editorial Revision.*

Discussion: Procedures for seismic isolation calculate design displacements directly. Additional modification of response using these coefficients is incorrect.

Resolution: A sentence was added in Prestandard Section 9.2.1 clarifying that coefficients C_1, C_2, C_3, and J shall be taken as 1.0 for seismically isolated structures.

9-4 **Chapter 9 Needs Controls for Proper Application**

Chapter 9 needs sufficient controls to ensure proper application of provisions.

Section: Chapter 9 – all.

Classification: *Recommended for Basic Research.*

Discussion: This issue was raised by the Project Advisory Committee who felt that the chapter was too complex and contains too much information to be properly applied by practicing engineers with limited experience.

Resolution: Unresolved pending future research.

10. Simplified Rehabilitation

Chapter 10 outlines the Simplified Rehabilitation Method. Simplified Rehabilitation is an alternative to Systematic Rehabilitation that can be used to achieve the Life Safety Performance Level in buildings that conform to certain type, size and regularity requirements. It is based on the provisions of FEMA 178, *NEHRP Handbook for the Seismic Evaluation of Existing Buildings*, and includes a cross-reference between the *Guidelines* and FEMA 178. It contains a section on amendments to FEMA 178, listing new potential deficiencies in building systems identified in earthquakes subsequent to the publication of FEMA 178. Chapter 10 also suggests specific corrective measures for the rehabilitation of certain deficiencies.

10.1 New Concepts

- Amendments to FEMA 178: Since the development and publication of FEMA 178, several damaging earthquakes have occurred. These earthquakes have exposed new potential deficiencies in building systems that were not addressed by the FEMA 178 methodology. The *Guidelines* contain amendments to FEMA 178 that incorporate lessons learned from these earthquakes.
- Simplified Rehabilitation: The localized correction of deficiencies is sufficient to rehabilitate simple buildings to the Life Safety Performance Level without the need for a full-scale global analysis.

10.2 Global Issues

10-1 **FEMA 310 as Basis for Chapter 10**

Chapter 10 is based on FEMA 178. FEMA 178 has since been fully updated with the publication of FEMA 310, *Handbook for the Seismic Evaluation of Buildings – A Prestandard*. FEMA 310 should be used as the basis for Chapter 10.

Section: All.

Classification: *Technical Revision.*

Discussion: FEMA 178, based on early 80's technology, is a force-based methodology that uses traditional building code force level analysis techniques. FEMA 310 includes issues identified in recent earthquakes, and utilizes a displacement-based analysis approach that is consistent with the methodology of the *Guidelines*.

Resolution: Chapter 10 of the Prestandard has been revised for consistency with FEMA 310.

10-2 **Simplified Rehabilitation Equivalent to BSO**

If Chapter 10 is revised to reference FEMA 310, can the Simplified Rehabilitation Method be judged to satisfy the Basic Safety Objective (BSO) for buildings eligible for simplified rehabilitation?

Section: 10.1.

Classification: *Non-persuasive.*

Discussion: This issue is related to issue 3-7. Limited performance expectations for buildings passing the Chapter 10 provisions were due in part to the lateral force level used in FEMA 178. FEMA 310 utilizes a displacement-based methodology consistent with the *Guidelines*, however, there are differences between the two methods. The analysis criterion in FEMA 310 is based on a single level of earthquake shaking hazard and the BSO requires a two-level approach consisting of life safety performance for the BSE-1 earthquake hazard level, and collapse prevention performance for the BSE-2 earthquake hazard level. It may not be reasonable to assume that the BSE-1 level evaluation will always govern. There are different *m*-values in the two documents, and FEMA 310 uses a 0.75 factor for a Tier 3 detailed evaluation using the procedures in the *Guidelines.*

Resolution: No change proposed.

10-3 **Chapter 10 Too Complex to be Simplified Rehabilitation**

The procedures of Chapter 10 are too complex to be considered Simplified Rehabilitation.

Section: Chapter 10 – all.

Classification: *Non-persuasive.*

Discussion: This issue was raised by the Project Advisory Committee who felt that the Chapter was too complex, particularly for buildings in regions of low seismicity. The PT considered this comment non-persuasive with the opinion that the checklist methodology and deficiency-only analysis and rehabilitation were not too complex, but only required more familiarity on the part of practicing engineers.

Resolution: No change proposed.

10-4 **Reconcile Differences Between FEMA 310 and FEMA 356**

Since the ASCE Standards Committee is producing both the evaluation standard and rehabilitation standard, the two documents should be consistent. In addition, FEMA 310 has been revised through the committee ballot process. Therefore, FEMA 356 should be checked and updated to reflect these changes.

Section: Chapter 10

Classification: Technical Revision

Discussion: The ASCE Standards Committee on Seismic Rehabilitation of Buildings is now responsible for producing both of the standards for seismic evaluation (FEMA 310) and seismic rehabilitation (FEMA 356). These two documents, while similar, were produced at different times in separate forums. FEMA 310 has already gone through standards committee ballot and has had numerous revisions. FEMA 356 has had many global topic studies performed, resulting in significant changes. The goal of these two documents is that they be used together. FEMA 310 would be used for the initial evaluation of buildings and FEMA 356 would be used either for advanced analysis or rehabilitation. Therefore, the two documents need to be checked for consistency against one another. Special Study 12 – FEMA 310 and FEMA 356 Differences was funded to research this issue further.

In examination of both documents, two major differences are apparent:

1. There is a difference in the seismic demands in evaluation versus design. The difference is philosophical and extends back to FEMA 178 when a 0.85 and 0.67 were applied to the static base shear. FEMA 310 was developed to maintain this consistency with FEMA 178. FEMA 356 is a rehabilitation document, so the forces remain at design level. After much discussion, it was decided that the difference would remain between the two documents since the documents are used for different purposes. However, FEMA 310 commentary would be revised to indicate that evaluation level demands would have a lower probability of achieving the desired performance level.

2. The FEMA 310 analysis methodology is less complex than FEMA 356. When FEMA 310 was developed, it was recognized that the requirements for evaluation should less strenuous than for rehabilitation. Therefore, only the LSP was used and the terms and analysis requirements were simplified. Other requirements, such as material properties and materials testing were also relaxed. Since the FEMA 310 methodology is really a simplified subset of FEMA 356, it was decided that the difference would remain, once again acknowledging the difference between evaluation and design.

Once these two differences were recognized, the two documents were very consistent. Changes to the methodology due to FEMA 356 global topic studies, such as foundations and period formulation, would be made to FEMA 310 during public ballot. Changes to definitions and cross-references due to the FEMA 310 ballot process would be made to FEMA 356 prior to standards committee ballot.

Resolution: Modify definitions in Chapter 10 of FEMA 356 to match FEMA 310. Update cross-references in Chapter 10 of FEMA 356 to reflect changes to FEMA 310.

11. Architectural, Mechanical, and Electrical Components
(Simplified and Systematic Rehabilitation)

Chapter 11 outlines the rehabilitation criteria for architectural, mechanical and electrical components, collectively referred to as nonstructural components. It defines nonstructural components and systems, describes the expected behavior, and outlines the acceptance criteria for various architectural, mechanical and electrical systems.

11.1 New Concepts

- Deformation-sensitive Components: Nonstructural components are classified as acceleration-sensitive, deformation-sensitive, or both. The *Guidelines* include specific acceptance criteria for evaluating drifts of deformation-sensitive nonstructural components.
- Designation of life safety considerations: The *Guidelines* specifically identify which nonstructural components and systems represent potential life safety concerns based on level of seismicity.
- Rehabilitation requirements for IO: The acceptance criteria include specific requirements for meeting the Immediate Occupancy Performance Level.
- Discussion of the Operational Performance Level: Prescriptive requirements for the Operational Performance Level are beyond the scope of the *Guidelines*, however, the *Guidelines* include a definition of it, and describe a procedure for developing Operational Performance criteria.

11.2 Global Issues

11-1 **Preservation of Egress Not Required**

Statements about preserving egress for the life safety performance level may not be necessary.

Section: 11.4.4.

Classification: *Non-persuasive.*

Discussion: Issues related to egress were specifically separated from requirements for the Life Safety Performance Level to avoid triggering unintended upgrades of emergency lighting, emergency power, disabled access, and security and fire alarm systems that are related to egress, but not directly related to seismic concerns. At the 3/3/99 Standards Committee meeting this issue was reclassified as non-persuasive.

Resolution: No change proposed.

11-2 **Extent of Nonstructural Investigation Unclear**

The *Guidelines* are not specific as to how many occurrences of typical conditions must be checked for each different nonstructural component.

Section: 11.2.

Classification: *Technical Revision.*

Discussion: In large buildings nonstructural components, such as light fixtures, can occur hundreds of times throughout the structure. There is no discussion regarding an appropriate level of investigation for nonstructural components (i.e.: does every fixture need to be inspected?).

Resolution: Prestandard Section 11.2.2 was created to specify nonstructural sample size. The new nonstructural sampling provisions are modeled after the comprehensive condition assessment provisions for structural components.

11-3 **Vertical Acceleration Criteria Missing**

Vertical accelerations as well as horizontal accelerations are required to be considered in the rehabilitation of canopies and marquees. Sections 11.7.3 and 11.7.4 do not specify vertical acceleration criteria.

Section: 11.7.3, 11.7.4.

Classification: *Technical Revision.*

Discussion: Related to issue 2-5 regarding inaccuracies in estimating vertical accelerations using the 2/3 factor.

Resolution: Prestandard Sections 11.7.3 and 11.7.4 have been revised to include equations for vertical acceleration based on 2/3 of horizontal acceleration. In 11.7.4, vertical acceleration has been separated from the requirements for variation over the height of the building.

11-4 **Effects of Nonstructural on Structural Response**

There is insufficient guidance on how to consider the effects of nonstructural components in the structural analysis of the building.

Section: 3.2.2.3, 11.5.1.

Classification: *Recommended for Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to further study the effects of nonstructural components on the behavior of the structure. Partial resolution should focus on providing additional commentary to highlight what guidance is provided.

Resolution: Unresolved pending future research.

11-5 Sensitivity of Nonstructural to Deformation

More information is needed regarding the sensitivity of nonstructural components to building deformations and drift.

Section: 11.6.

Classification: *Recommended for Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to further research the interaction between structural movements and nonstructural components, particularly glass, heavy cladding, and components and re-entrant corners.

Resolution: Unresolved pending future research.

11-6 Glazing Acceptance Criteria Outdated

The analysis and acceptance criteria for glazed exterior wall systems is not consistent with the latest research.

Section: 11.9.1.5.

Classification: *Application of Published Research.*

Discussion: Recent published research on this topic include the following: Behr, R.A., et al, "Seismic Performance of Architectural Glass in a Storefront Wall System", EERI Spectra, vol. 11, no. 3, 8/95; Pantelides, C.P., et al, "Dynamic In-plane Racking Tests of Curtain Wall Glass Elements", Earthquake Engineering and Structural Dynamics, vol. 23, 1994, among others. Changes to these provisions would be consistent with proposed changes to other documents governing glazed exterior wall systems.

Resolution: Prestandard Section 11.9.1.5 has been revised to incorporate new definitions of glazed exterior wall systems, and new analysis and acceptance criteria based on the referenced research.

11-7 Acceptance Criteria Needed for Other Performance Levels

Acceptance criteria for nonstructural components specified in Chapter 11 refer only to the Life Safety Performance Level and the Immediate Occupancy Performance Level. Other levels are not covered.

Section: Chapter 11, all, Table 11-1, Section 1.5.2.4.

Classification: *Technical Revision.*

Discussion: The Operational Performance Level is outside the current scope of the Prestandard. The nonstructural performance criteria for the Life Safety Performance Level was intended to be the basis for the Hazards Reduced criteria. Special Study 13 – Study of Nonstructural Provisions was funded to research this issue further.

Resolution: Prestandard Section 11.3.2 has been revised to state that analysis and rehabilitation requirements for the Hazards Reduced Performance Level shall follow the requirements for the Life Safety Performance Level. The definition of Hazards Reduced Nonstructural Performance has been clarified in Prestandard Section 1.5.2.4. Prestandard Table 11-1 has been revised to explicitly define the subset of nonstructural components addressed by the Hazards Reduced Performance Level.

11-8 **Equation 11-2 (11-3) Variation with Height**

Equation 11-2 used to calculate the seismic force on nonstructural components varies in an inverted triangular distribution over the height of the building. This distribution is not justified by recorded data or dynamic analysis results.

Section: 11.7.4, Equation 11-2 (new equation 11-3).

Classification: *Application of Published Research and Basic Research.*

Discussion: The equation in the *Guidelines* is consistent with the 1997 NEHRP Provisions and the 1997 UBC. This issue was raised by the SC in response to the unofficial letter ballot of the Prestandard.

Resolution: Unresolved pending further study of available information and future research.

11-9 **Heavy Partitions—Scope and Definition**

In zones of low seismicity, the *Guidelines* should require heavy partitions to be reviewed for adequacy. In Section 11.9.2.1 heavy is defined as greater than 5 psf, which means metal stud and gypsum board partitions would fall under this classification.

Section: 11.9.2.1, Table 11-1.

Classification: *Technical Revision.*

Discussion: Review of heavy partitions in regions of low seismicity was considered by the Prestandard PT and found non-persuasive. The evaluation procedure in the *Guidelines* was judged appropriate, although the 5 psf limitation is not consistent with what was intended to be heavy (masonry partitions).

Resolution: Prestandard Section 11.9.2.1 was revised to omit the 5 psf criteria for heavy partitions. Table 11-1 remains unchanged with regard to evaluation of heavy partitions.

11-10 **Guidance on Nonstructural Operational Performance Needed**

Guidance is needed on establishing nonstructural Operational Performance acceptance criteria.

Section: 11.3.2

Classification: *Application of Published Research.*

Discussion: Related to issue 11-7 regarding acceptance criteria for other performance levels. Nonstructural Operational Performance is outside the current scope of the Prestandard. This issue was raised by the SC in response to the unofficial letter ballot of the Prestandard.

Resolution: Unresolved pending further study of available information.

11-11 **Nonstructural IO and LS Criteria need calibration**

The distinction between nonstructural IO and LS performance criteria needs investigation. Design forces for each performance level need to be calibrated between the two methods.

Section: 11.7.3, 11.7.4, 11.9

Classification: *Recommended for Basic Research.*

Discussion: Throughout Section 11.9, references to Sections 11.7.3 and 11.7.4 are made for seismic design force criteria. For LS, either section is permissible, but for IO only 11.7.4 is used. The equations in 11.7.3 are conservative empirical equations that are always greater than those in 11.7.4. This results in LS force levels that can be more stringent than IO force levels, depending on the method chosen. This issue was raised by the SC in response to the unofficial letter ballot of the Prestandard.

Resolution: Unresolved pending future research.

11-12 **Storage Racks as Non-Building Structures**

Storage racks should be treated differently than other nonstructural components because they behave more like a multi-story building than a rigid block. Provisions should be developed to address non-building type structures.

Section: 11.7.3, 11.7.4, 11.11.1.3

Classification: *Application of Published Research.*

Discussion: This issue was raised by the SC in response to the unofficial letter ballot of the Prestandard.

Resolution: Unresolved pending further review of available information.

11-13 **Floating Concrete Isolation Floors are not Addressed**

Isolation floors consisting of concrete slabs "floating" above the structural slab on a layer of isolation material are not addressed by the *Guidelines.*

Section: 11.9

Classification: *Recommended for Basic Research*

Discussion: This type of isolation floor system has been used on occasion in the past and is gaining popularity. To maintain the integrity of the noise or vibration barrier, the concrete slab is not anchored to the structural system, but should be restrained by a system of curbs or keys. Direction on how to address these systems is needed in the Prestandard.

Resolution: Unresolved pending future research.

Appendices

A. Miscellaneous Issues

This section addresses miscellaneous issues that are not directly related to any one chapter of the FEMA 273 *Guidelines*.

A.1 Global Issues

A-1 **Reference to Other Standards Incomplete**

References to other standards (e.g. ACI 318) throughout the *Guidelines* are not sufficient to determine how to apply them properly.

Section: All.

Classification: *Technical Revision.*

Discussion: None.

Resolution: Specific occurrences have been identified in the development of the Prestandard and additional direction has been provided on a case-by-case basis.

A-2 **Quality Assurance Not Specified**

The *Guidelines* are generally silent on design quality assurance provisions related to computer codes, engineer qualifications, peer reviews, and plan checking.

Section: All.

Classification: *Non- persuasive.*

Discussion: The omission of specific guidance on design quality assurance is inconsistent with the requirements for materials testing and construction inspection. At the 3/3/99 Standards Committee meeting this issue was reclassified as non-persuasive.

Resolution: No changes proposed.

A-3 **Permissive Language Not Standard Compatible**

Permissive language present in the *Guidelines* is not compatible with the provisions of a standard. Consider the use of the term "authority having jurisdiction" (AHJ) in the document to allow permissive requirements to be tightened as decided by local jurisdictions.

Section: All.

Classification: *Editorial Revision.*

Discussion: The purpose of the prestandard effort is to convert the verbiage of the *Guidelines* to standards language. Permissive requirements have been tightened where possible and where appropriate. It is implied in every code or standard that the authority having jurisdiction has the authority to specify criteria or approve alternative rational analysis procedures. It is not necessary to add this phrase throughout the standard.

Resolution: In the Prestandard permissive requirements have been converted to standards language. Where it is appropriate for leeway to remain in the provisions, the term "or approved" has been used. In Chapter 1, implications that the building owner has the authority to enforce the provisions of this standard have been removed.

A-4 **Triggers for Seismic Rehabilitation Missing**

Should enabling statements and triggers for seismic rehabilitation be added?

Section: All.

Classification: *Non-persuasive.*

Discussion: At the 3/3/99 Standards Committee meeting this issue was reclassified as non-persuasive. The decision regarding triggers for mandatory rehabilitation is a policy decision intentionally left to the local authority having jurisdiction.

Resolution: No changes proposed.

A-5 **Drift Limits Omitted**

Drift limits and acceptance criteria based on calculation of interstory drift are not included in the document.

Section: All.

Classification: *Non-persuasive.*

Discussion: A displacement base analysis procedure eliminates the need for drift limits. The analysis methodology evaluates the acceptability of elements in their displaced state at maximum expected displacements. Since displacements and their effects are explicitly calculated, drift limits are not relevant.

Resolution: No change proposed.

A-6 **Behavior of Rehabilitated Elements**

More information is needed regarding the behavior of rehabilitated elements and components.

Section: Chapters 5, 6, 7 and 8.

Classification: *Recommended for Basic Research (previously unresolved).*

Discussion: Upon completion of the *Guidelines*, BSSC identified the need to conduct additional research on the behavior of rehabilitated elements.

Resolution: Unresolved pending future research.

A-7 Expected and Lower Bound Strengths Unclear

The concepts of expected strength and lower bound strength are not clearly defined or used consistently throughout the document.

Section: Section 2.9.4 (new section 2.4.4), Chapters 5, 6, 7, and 8.

Classification: *Technical Revision.*

Discussion: This issue is related to issues 5-2 and 8-6. It is not clear what material properties should be used in the calculation of expected strength and lower bound strength. It is also not clear if default properties provided in the document are expected or lower bound properties, or if specified material properties are considered expected or lower bound. The correct use of strength reduction (ϕ) factors is not clearly stated.

Resolution: Prestandard Section 2.4.4 has been revised to clearly introduce the concept of expected and lower bound strengths and material properties. Expected material properties have been defined as mean values of tested properties. Lower bound material properties have been defined as mean minus one standard deviation of tested material properties. All relevant sections have been revised to state that $\phi = 1.0$ in all cases when strength reduction factors are used in the calculation of expected or lower bound strengths. All references to default values have been made consistent with lower bound material properties, with the exception of Chapter 8. Default wood material properties are considered expected material properties. All references to expected and lower bound strengths in Chapters 5, 6, 7 and 8 have been revised to be consistent with this revision.

A-8 Paragraphs Contain Multiple Provisions

Many paragraphs throughout the *Guidelines* contain multiple provisions and several important concepts lumped together. Lists throughout the *Guidelines* have bullet points that are not numbered. In codes and standards, major concepts and mandatory provisions are usually separated and numbered individually.

Section: All.

Classification: *Editorial Revision.*

Discussion: This issue was raised at the 3/3/99 Standards Committee meeting. Separation and numbering of major concepts and mandatory provisions will make it easier to locate or cross-reference between requirements.

Resolution: Long paragraphs with multiple provisions in the Prestandard have been split and numbered individually to the extent possible. Sections with letter designations have been revised to numeric designations only. Bulleted lists in the Prestandard have been numbered sequentially.

A-9 **Rehabilitation Measures as Commentary**

Sections describing specific rehabilitation measures for various structural systems should not be mandatory. Engineers should be free to determine an appropriate rehabilitation measure that meets the acceptance criteria.

Section: All.

Classification: *Editorial Revision.*

Discussion: This issue was raised at the 3/3/99 Standards Committee meeting. Inclusion of rehabilitation measures in the standard implies they are mandatory and limits options for rehabilitating buildings.

Resolution: Prestandard Section 2.5, Rehabilitation Strategies, has been left in the standard. This section describes the overall general approach to rehabilitation. All other sections that describe specific rehabilitation measures in Chapters 5 through 8 of the Prestandard have been shifted to commentary.

A-10 **Standard/Commentary Split**

The First SC Draft of the Prestandard contains text that is not mandatory itself, or necessary to the mandatory requirements of the document. The split between standard and commentary needs to be improved to reduce the text of the standard to the mandatory requirements alone.

Section: All.

Classification: *Editorial Revision.*

Discussion: This issue was raised at the 3/3/99 Standards Committee meeting.

Resolution: The split between standard and commentary in the Prestandard has been reviewed in each subsequent draft since the First SC Draft. Non-mandatory verbiage has been removed from the Prestandard to the extent possible.

A-11 **No Acceptance Criteria for Secondary IO**

The *Guidelines* have no acceptance criteria for secondary components at the IO performance level.

Section: All.

Classification: *Editorial Revision.*

Discussion: Because the Immediate Occupancy Performance Level is related to damage control, the intent of the *Guidelines* is that acceptability for IO performance is not related to primary or secondary element classifications. Components damaged to the extent they are performing at the secondary limits of response do not meet the intent of IO performance. This means that components which might otherwise be classified as secondary for other performance levels, may end up controlling a design for the IO performance level.

Resolution: Tables of acceptance criteria in the Prestandard have been revised to remove IO from under the heading of "Component Type" to clarify that IO criteria is independent of primary or secondary classifications.

A-12 **Acceptance Criteria for Archaic Materials Needed**

Some archaic materials such as hollow clay tile and plain concrete do not have explicit acceptance criteria or modeling information in the *Guidelines*. A procedure should be developed, other than testing, to estimate this information when engineering data is available.

Section: All, 2.13 (new section 2.8).

Classification: *Recommended for Basic Research.*

Discussion: None.

Resolution: Unresolved pending future research.

B. Research and Study Needs

To facilitate future improvements to the *Prestandard*, this section summarizes issues that are currently unresolved and recommended for basic research. Issues are listed in numerical order.

2-1 **Overturning Appears Overly Conservative**

Overturning calculations at pseudo lateral force levels appear to be overly conservative and can predict overturning stability problems that are not well correlated with observed behavior.

2-2 **Ground Motion Pulses Not Covered**

Ground motion duration and pulses are not explicitly considered in the analysis procedures except for the use of higher acceleration values specified in regions near active faults.

2-6 **Baseline Adjustments to Acceptance Criteria Needed**

Use of experimental data to set acceptance criteria has led to some inconsistency in calculated versus expected results. It may be appropriate to consider some baseline adjustments to acceptance parameters.

2-7 **Software Not Commercially Available**

Nonlinear software capable of performing 3-D nonlinear analyses is not commercially available to the building engineering community. Any building that requires this analysis based on *Guidelines* provisions cannot be rehabilitated to meet the provisions.

2-10 **No Public Input or Consensus on Acceptable Risk**

The present definitions of performance levels and acceptable risk have been developed by engineers with little input from the public, and may not be consistent with popular notions.

2-19 **Upper Limit on DCRs for LSP Needed**

There should be an upper limit on DCR values that should not be exceeded if linear procedures are to be applicable, regardless of the presence or absence of structural irregularities.

2-23 **R_{OT} Needed for IO Performance**

An overturning force reduction factor, R_{OT}, for IO performance is needed to complete the alternative procedure for evaluating overturning stability.

2-24 **LS Performance Level Should be Clarified or Eliminated**

The Life Safety Performance Level should be more clearly defined in terms of structural performance, or it should be eliminated as a performance goal.

2-25 **The 2/3 Factor Estimating Vertical Seismic Forces is Not Accurate**
The 2/3 factor used to estimate the relationship between vertical response spectra and horizontal response spectra is not accurate.

2-26 **Additional Guidance on Damping Needed**
There is more variation in damping of actual buildings than addressed in the document. Additional guidance on damping values is needed.

2-28 **Equation for Building Separation is Overconservative**
Equation (2-16) for required building separation based on SRSS combination of building displacements is overconservative.

3-1 **Ct=0.06 for Wood Buildings Not Documented**
The accuracy of C_T =0.06 for use in the period calculation for small wood buildings is not documented.

3-4 **Multidirectional Effects Need Clarification**
Further direction on consideration of multidirectional effects, including vertical seismic forces, is required.

3-6 **NSP Uniform Load Pattern Overly Conservative**
The shape of the loading pattern used in NSP significantly affects the results. Specifying a uniform load pattern appears to be overly conservative and can dominate the resulting behavior.

3-10 **Upper Limit on Pseudo Lateral Force**
The LSP forces appear to be too high. FEMA 273 does not contain an upper bound limit on maximum base shear similar to the 0.75W limit in FEMA 310.

3-13 **LSP and NSP Results Need Calibration**
The Linear Static Procedure is not always more conservative than Nonlinear Static Procedure.

3-14 **Reliability Information Not Provided**
No specific information on reliability is provided in the *Guidelines*.

3-15 **LSP Should be a Displacement Calculation**
The Linear Static Procedure should be changed to a displacement-based calculation procedure.

3-17 **C1 Factor Overly Conservative**
Introduction of the C_1 factor overly penalizes buildings with short calculated fundamental periods.

3-18 **Duration Effects Not Considered**

The analytical procedures of the *Guidelines* do not consider duration effects to take into account cyclic degradation.

3-19 **Marginal Gravity Load Capacity Not Considered**

Further study of LSP acceptance criteria is required for building components with marginal gravity load capacity.

3-20 **Inelastic Cyclic Properties Needed**

More information is needed to develop inelastic cyclic component properties for use in complex nonlinear dynamic analyses.

3-23 **Substantiation of C1, C2, C3 Needed**

Further research is needed to substantiate the coefficients C_1, C_2, and C_3.

3-30 **Application of η-factor is Overconservative**

Amplifying forces and displacements by the η-factor to account for torsion is overconservative for lateral force resisting elements located near the center of rigidity.

3-34 **Alternate Empirical Period Calculation for Flexible Diaphragms**

An alternate empirical equation can be developed for single span flexible diaphragms consisting of $T=C_{td}\,(L)^{1/2}$, where L is the span length and C_{td} is a materials based coefficient.

3-36 **Application of the NSP With Non-Rigid Diaphragms Needs Revision**

Further guidance is required on the proper application of the NSP in buildings with non-rigid diaphragms.

3-38 **Procedures for Torsional Amplification are Unconservative**

Procedures for torsional amplification do not account for torsional degradation and are unconservative in determining increased forces and displacements for this effect.

4-3 **Lateral Soil Spring Procedure Needs Refinement**

The procedure for developing lateral soil spring stiffness based on displacement results in unrealistically high calculated lateral soil pressures. More information is needed on the force-displacement behavior of geotechnical materials and foundations under short term loading.

4-4 **Nonlinear Soil Spring Information Needed**

More information is needed on nonlinear force-displacement behavior of foundation systems for inclusion in nonlinear analyses.

5-1 ***m*-factors Appear Overly Conservative**
Certain values of acceptance criteria (*m*-factors) and deformation limits for steel components appear to be too conservative.

5-14 **Steel Acceptance Criteria is Based on Component Length**
Nonlinear acceptance criteria for certain steel components are expressed as a multiple of yield rotation, which is based on the length of the component.

5-15 **The Ratio Between IO and LS Acceptance Criteria Appears Too Large**
The ratio between IO and LS acceptance criteria for certain steel components appears to be too large. IO values for these components appear to be too low.

5-16 **Nonlinearity is Permitted in Column Base Plates**
For certain controlling actions, nonlinearity is permitted in column base plates. Column bases should be treated as force-controlled.

6-1 ***m*-factors Appear Overly Conservative**
Certain values of acceptance criteria (*m*-factors) and deformation limits for concrete components appear to be too conservative and are not consistent with other chapters. Of particular concern is an inconsistency with Chapter 7, Masonry.

6-17 **Acceptability for Columns in Tension Missing**
Acceptability requirements for concrete columns in tension are not provided.

6-18 **Calculation of M_y for Shearwalls Unconservative**
The procedure in Section 6.8.2.3 for calculating the yield moment of reinforced concrete wall sections may underestimate the actual flexural capacity. This result would be unconservative for use in a limit state analysis.

6-20 **Concrete Flange Provisions Unconservative**
Provisions for flanged sections in Section 6.4.1.3 may underestimate the frame action of the system when applied to joist construction.

7-1 ***m*-factors Appear Overly Conservative**
Certain values of acceptance criteria (*m*-factors) and deformation limits for masonry components appear to be too conservative and are not consistent with other chapters. Of particular concern is an inconsistency with Chapter 6, Concrete.

7-4 **Guidance for Infill Panels with Openings Needed**
Evaluation of masonry infills does not provide adequate guidance for addressing masonry infill panels with openings.

7-10 **Masonry Shear Strength Based on Average Test Values is Unconservative**
The calculation of expected masonry shear strength using average values of brick shear tests overestimates the actual shear strength.

7-11 **URM Shear Strength Should be Force-Controlled**
Shear strength of URM walls is brittle and unreliable and should be treated as a force-controlled action.

8-1 ***m*-factors Appear Overly Conservative**
Certain values of acceptance criteria (*m*-factors) and deformation limits for wood components appear to be too conservative.

9-1 **Procedures Require Validation**
Analytical procedures for energy dissipation systems require validation.

9-4 **Chapter 9 Needs Controls for Proper Application**
Chapter 9 needs sufficient controls to ensure proper application of provisions.

11-4 **Effects of Nonstructural on Structural Response**
There is insufficient guidance on how to consider the effects of nonstructural components in the structural analysis of the building.

11-5 **Sensitivity of Nonstructural to Deformation**
More information is needed regarding the sensitivity of nonstructural components to building deformations and drift.

11-8 **Equation 11-2 (11-3) Variation with Height**
Equation 11-2 used to calculate the seismic force on nonstructural components varies in an inverted triangular distribution over the height of the building. This distribution is not justified by recorded data or dynamic analysis results.

11-10 **Guidance on Nonstructural Operational Performance Needed**
Guidance is needed on establishing nonstructural Operational Performance acceptance criteria.

11-11 **Nonstructural IO and LS Criteria need calibration**
The distinction between nonstructural IO and LS performance criteria needs investigation. Design forces for each performance level need to be calibrated between the two methods.

11-12 **Storage Racks as Non-Building Structures**
Storage racks should be treated differently than other nonstructural components because they behave more like a multi-story building than a rigid block. Provisions should be developed to address non-building type structures.

11-13 **Floating Concrete Isolation Floors are not Addressed**

Isolation floors consisting of concrete slabs "floating" above the structural slab on a layer of isolation material are not addressed by the *Guidelines.*

A-6 **Behavior of Rehabilitated Elements**

More information is needed regarding the behavior of rehabilitated elements and components.

A-12 **Acceptance Criteria for Archaic Materials Needed**

Some archaic materials such as hollow clay tile and plain concrete do not have explicit acceptance criteria or modeling information in the *Guidelines*. A procedure should be developed, other than testing, to estimate this information when engineering data is available.