# Contents

**Preface** . . . . . **iii**

**Figures** . . . . . **vii**

**Tables** . . . . . **ix**

**1. Introduction** . . . . . **1**
1.1 Purpose and Scope of the Guide . . . . . 1
1.2 Road Map . . . . . 1
1.3 Vibration Limits . . . . . 2
1.4 Floor Vibration Models . . . . . 2
1.4.1 Resonance Model . . . . . 2
1.4.2 Point-Deflection Model . . . . . 3
1.4.3 Impulse-Vibration Model . . . . . 3

**2. Design** . . . . . **5**
2.1 Vibration Due to Walking in Light-Frame Construction . . . . . 5
2.1.1 Design Criterion . . . . . 5
2.1.2 Application to Light-Frame Floor Structures . . . . . 5
2.1.3 Additional Design Considerations . . . . . 6
2.2 Vibration Due to Walking in Steel and Concrete Construction . . . . . 8
2.2.1 Design Criterion . . . . . 8
2.2.2 Application to Beam (or Joist) and Girder Floor Systems . . . . . 9
2.3 Rhythmic Activities . . . . . 10
2.3.1 Design Criterion . . . . . 10
2.3.2 Design Procedure and Design Aids . . . . . 12

**3. Retrofit** . . . . . **15**
3.1 Evaluation of Floor Vibration Problems . . . . . 15
3.1.1 Determining When to Evaluate . . . . . 15
3.1.2 Determining Source of Vibration . . . . . 15
3.1.3 Evaluation Tools . . . . . 15
3.2 Retrofits of Light-Frame Construction . . . . . 16
3.2.1 Overall Procedure . . . . . 16
3.2.2 Support Correction . . . . . 16
3.2.3 Transverse Floor Stiffening . . . . . 16
3.3 Retrofit Strategies for Steel and Concrete Construction . . . . . 16
3.3.1 Reduction of Effects . . . . . 16
3.3.2 Relocation . . . . . 16
3.3.3 Changing Floor Mass . . . . . 17
3.3.4 Stiffening . . . . . 17
3.3.5 Damping Increase . . . . . 17

3.3.6 Isolation . . . 18
3.3.7 Active Control . . . 18
3.4 Retrofit Strategies for Machine-Induced Vibrations . . . 18
3.4.1 General Strategies . . . 18
3.4.2 Base-Isolation of Machinery . . . 18

**4. Estimation of Floor Vibration Properties . . . 21**
4.1 Floor Panel Stiffness . . . 21
4.1.1 Deflection Due to Concentrated Load . . . 21
4.1.2 Deflection Due to Uniformly Distributed Load . . . 22
4.1.3 Flexural Stiffness, *EI*, for Light-Frame Construction . . . 22
4.1.4 *EI* for Steel and Concrete Deck Construction . . . 23
4.1.5 *EI* for Concrete Construction . . . 24
4.1.6 Transverse Stiffness . . . 24
4.2 Natural Frequency . . . 25
4.2.1 General Methods for Estimating Natural Frequency . . . 25
4.2.2 Estimation of Panel Deflection, $\Delta$ . . . *25*
4.2.3 Natural Frequency of Concrete Floor Systems . . . 26
4.2.4 Natural Frequency of Light-Frame Floor Systems . . . 26
4.3 Effective Floor Weight (Mass) . . . 26
4.3.1 Effective Weight per Unit Area, *w* . . . *26*
4.3.2 Effective Weight, *W* . . . *27*
4.3.3 Effective Weight of Concrete Floor Systems . . . 28
4.3.4 Effective Weight of Light-Frame Floor Systems . . . 28
4.4 Damping Ratio, $\beta$ . . . 28

**5. Examples . . . 29**
5.1 Vibration Due to Walking in Light-Frame Construction . . . 29
5.1.1 Wood I-Joist Residential Floor (Design) . . . 29
5.1.2 Wood Truss Residential Floor (Design) . . . 30
5.2 Vibration Due to Walking in Steel and Concrete Construction . . . 31
5.2.1 Precast Double-T Mall Footbridge (Design) . . . 31
5.2.2 Hollowcore Office Floor (Design) . . . 32
5.2.3 Steel Office Floor (Retrofit) . . . 33
5.3 Rhythmic Activities . . . 34
5.3.1 Glulam Dance Floor (Design) . . . 34
5.3.2 Precast Concrete Stadium Seats (Design) . . . 35
5.3.3 Steel Joist Aerobics Floor (Retrofit) . . . 36
5.4 Machine-Induced Vibration . . . 37
5.4.1 Base Isolation of a Machine on a Light-Frame Floor (Retrofit) . . . 37

**Appendix A. Determination of Floor Panel Stiffness: Examples . . . 39**
A.1 Wood I-Joist Floor Panel Stiffness . . . 39
A.2 Precast Stadium Seating Panel Stiffness . . . 40

**Symbols . . . 43**

**References . . . 47**

**Project Participants . . . 49**

**Applied Technology Council Projects and Report Information . . . 51**

**Applied Technology Council Directors . . . 63**