Concrete Shear Wall Design

Complete coverage of earthquake-resistant concrete building design Written by a renowned seismic engineering expert, this authoritative resource discusses the theory and practice for the design and evaluation of earthquakeresisting reinforced concrete buildings. The book addresses the behavior of reinforced concrete materials, components, and systems subjected to routine and extreme loads, with an emphasis on response to earthquake loading. Design methods, both at a basic level as required by current building codes and at an advanced level needed for special problems such as seismic performance assessment, are described. Data and models useful for analyzing reinforced concrete structures as well as numerous illustrations, tables, and equations are included in this detailed reference. Seismic Design of Reinforced Concrete Buildings covers: Seismic design and performance verification Steel reinforcement Concrete Confined concrete Axially loaded members Moment and axial force Shear in beams, columns, and walls Development and anchorage Beam-column connections Slab-column and slab-wall connections Seismic design overview Special moment frames Special structural walls Gravity framing Diaphragms and collectors Foundations As software skills rise to the forefront of design concerns, the art of structural conceptualization is often minimized. Structural engineering, however, requires the marriage of artistic and intuitive designs with mathematical accuracy and detail. Computer analysis works to solidify and extend the creative idea or concept that might have started o

"With the rise in constructing using FRP reinforcement, owing to corrosion problems in steel-reinforced structures, there is a need for a system to resist lateral loads induced from wind and earthquake loads. The present study addressed the applicability of reinforced-concrete shear walls totally reinforced with glass-fiber-reinforced polymer (GFRP) bars to attain reasonable strength and drift requirements as specified in different codes. Four large-scale shear walls - one reinforced with steel bars (as reference specimen) and three totally reinforced with GFRP bars - were constructed and tested to failure under quasi-static reversed cyclic lateral loading. The GFRP-reinforced walls had different aspect ratios covering the range of medium-rise walls. The reported test results clearly showed that properly designed and detailed GFRPreinforced walls could reach their flexural capacities with no strength degradation, and that shear, sliding shear, and anchorage failures were not major problems and could be effectively controlled. The results also showed recoverable and self-centering behavior up to allowable drift limits before moderate damage occurred and achieved a maximum drift meeting the limitation of most building codes. Acceptable levels of energy dissipation accompanied by relatively small residual forces, compared to the steel-reinforced shear wall, were observed. Finite element simulation was conducted and the analyses captured the main features of behavior. Interaction of flexural and shear deformations of the tested shear walls was investigated. It was found that relying on the diagonal transducers tended to overestimate shear distortions by 30% to 50%. Correcting the results based on the use of vertical transducers was assessed and found to produce consistent results. Decoupling the flexural and shear deformations was discussed. Using GFRP bars as elastic material gave uniform distribution of shear strains along the shear region, resulting in shear deformation ranging from 15 to 20% of total deformation. The yielding of the steel bars intensified the shear strains at the yielding location, causing significant degradation in shear deformation ranging from 2 to 40% of total deformation. The results obtained demonstrated significantly high utilization levels of such shear wall type, therefore, primary guidelines for seismic design of GFRP-reinforced shear wall in moderate earthquakes regions was presented, as no design guidelines for lateral load resistance for GFRP-reinforced walls are available in codes. The ultimate limit state was addressed by providing strength capacity that limit ductility demand to their safe flexural displacement capacity. The strength demands were derived from ground motion spectra using modification factors that depend on both the strength and energy absorption of the structure. Deformation capacity was derived by proposing new definitions for elastic (virtual yield) displacement and maximum allowable displacement. Strength modification factor was proposed based on the test results. The occurrence of "virtual plastic hinge" for GFRP-reinforced shear walls was described providing new definitions convenient with the behavior of the GFRP-reinforced shear walls. "Virtual plastic hinge" length was estimated based on observations and calculations. Subsequently, the experimental results were used to justify the proposed design procedure. The promising results could provide impetus for constructing shear walls reinforced with GFRP bars and constitute a step toward using GFRP reinforcement in such lateral-resisting systems."

This book is a state-of-the-art report on the ductility of steel structures, containing a comprehensive review of the technical literature available, and presenting the results of the authors' own extensive research activities in this area. Analytical and numerical methods are described, and a wealth of practical information is provided. Ductility of Seismic-Resistant Steel Structures will be of great use to advanced students, researchers, designers and professionals in the field of civil, structural and earthquake engineering.

The quality and testing of materials used in construction are covered by reference to the appropriate ASTM standard specifications. Welding of reinforcement is covered by reference to the appropriate AWS standard. Uses of the Code include adoption by reference in general building codes, and earlier editions have been widely used in this manner. The Code is written in a format that allows such reference without change to its language. Therefore, background details or suggestions for carrying out the requirements or intent of the Code portion cannot be included. The Commentary is provided for this purpose. Some of the considerations of the committee in developing the Code portion are discussed within the Commentary, with emphasis given to the explanation of new or revised provisions. Much of the research data referenced in preparing the Code is cited for the user desiring to study individual questions in greater detail. Other documents that provide suggestions for carrying out the requirements of the Code are also cited.

Reinforced concrete structural (shear) walls are commonly used as lateral load resisting systems in high seismic zones because they provide significant lateral strength, stiffness, and deformation capacity. Understanding the response and behavior of shear walls is essential to achieve more economical and reliable designs, especially as performance-based design approaches for new buildings have become more common. Results of a case study of 42-story RC dual system building, designed using code-prescriptive and two different performance-based

design approaches, are presented to assess expected performance. Median values and dispersion of the response quantities are, in general, well-below acceptable limits and the overall behavior of the three building designs are expected to be quite similar. However, the ability to define shear failure and collapse proved difficult and provided motivation to conduct additional studies. For both design of new buildings and evaluation/rehabilitation of existing structural wall buildings, an accurate assessment of median (expected) and dispersion of wall shear strength and deformation capacity are needed. A wall test database (124 specimens) was assembled to investigate the influence of various parameters on wall shear strength and deformation capacity, and to recommend alternative relations for strength and deformation capacity depending on expected wall behavior. Test results indicated that ACI 318-11 underestimates the shear strength of the shear-controlled walls. Mean curvature ductility ratios were obtained as about 3 and 7 for shear- and flexure-controlled walls, respectively. The new relations will allow improved damage and failure assessment of buildings utilizing structural walls for lateral load resistance. Failure assessment of RC shear walls also was conducted for the 15-story Alto Rio building which collapsed in the 2010 Chile earthquake. Possible reasons for collapse were identified using post-earthquake observed damage, structural drawings, and nonlinear static and dynamic response analyses. Analysis results indicate that collapse was likely influenced by various factors, including compression failure at the web boundary of T-shaped walls on the east side of the building, large shear demands at the filled-in corridor walls at the first level, and tensile fracture and splice failures at the west side of the building. Nonlinear modeling and analysis of the four-story RC building that was tested on E-Defense shaking table (2010) was investigated to assess current modeling approaches and assumptions, and to identify issues that require additional study. Including concrete tension strength, stiffness degradation, and strength degradation significantly improved the correlation between the analytical and test results.
Third Printing, incorporating errata, Supplement 1, and expanded commentary, 2013.
Concrete Structures StandardThe design of concrete structuresBuilding Code Requirements for Structural Concrete (ACI 318M-08) and CommentaryMinimum Design Loads for Buildings and Other StructuresAmer Society of Civil Engineers
Emphasizes actual structural design, not analysis, of multistory buildings for seismic resistance. Strong emphasis is placed on specific detailing requirements for construction. Fundamental design principles are presented to create buildings that respond to a wide range of potential seismic forces, which are illustrated by numerous detailed examples. The discussion includes the design of reinforced concrete ductile frames, structural walls, dual systems, reinforced masonry structures, buildings with restricted ductility and foundation walls. In addition to the examples, full design calculations are given for three prototype structures.
"This is the sixth edition of CSA A23.3, Design of concrete structures. It

supersedes the previous editions published in 2004, 1994, 1984, 1977 (metric), and 1973 (imperial), and 1959. This Standard is intended for use in the design of concrete structures for buildings in conjunction with CSA A23.1/A23.2, Concrete materials and methods of concrete construction/Methods of test and standard practices for concrete, and CSA A23.4, Precast concrete - Materials and construction. Changes in this edition include the following: a) Clause 3.1 contains new definitions for conventional construction, moderately ductile wall systems, different types of tilt-up construction, and gravity-load resisting frames. b) Clause 7.4.3.1 contains new requirements for the clear distance between pretensioning wires or strands at the ends of members. Clause 7.6.5 contains new requirements for additional column ties in column-slab connections over the slab depth where the slab is discontinuous. In Clause 7.6.4, the minimum diameter of spiral reinforced has been changed to 10 mm and the limit of one-sixth of the core diameter for the clear spacing between successive turns in a spiral has been removed. Clause 7.7.3 has new requirements for column ties in beam-column joints. c) Clause 9.2.1.2 gives guidance on stiffnesses to be used in members of lateral load resisting systems for wind loading. Clause 9.8 provides cautionary notes on member minimum thickness requirements and accounting for construction stages and early loading in computing deflections. d) Clause 10.9.4 contains a new requirement for the required ratio of spiral reinforcement. Clause 10.10.4 has increased the maximum factored axial load resistance of spirally reinforced columns and contains new provisions for the resistance of compression members as a function of wall thickness. Clause 10.16.3 provides a new factor for determining the amplitude of sway moments. e) Changes to the shear design provisions in Clause 11 include the following: the need to account for cover spalling for members subjected to high shear stress; new requirement for sections near supports; definition of special member types; accounting for effect of bars terminated in the flexural tension zone; and increased spacing limit for transverse reinforcement for special cases. Changes to the strut-and-tie design provisions of Clause 11.4 include the following: introduction of refined strut-and-tie models; modelling of members subjected to uniform loads; revised strut dimensions for struts anchored by reinforcement and for struts in narrow part of fanning compression regions; simplified expression for limiting compressive stress in struts; new detailing requirements for anchorage of ties; and provisions accounting for confinement of bearing in nodal regions. f) Clause 13 on two-way slab systems has been revised to include the following: the use of dv in determining the one-way shear resistance; new details for bottom bars in column strips of slabs with drop panels (see Figure 13.1); and a change in the definition of Vse for the design of structural integrity reinforcement (see Clauses 13.10.6.1 and 3.2). g) Clause 14 contains a new requirement to account for strong axis bending in bearing walls and new wall thickness requirements and slenderness requirements for flexural shear walls. h) Clause 18.3.1 permits a higher compressive stress limit in the concrete at transfer at the ends of simply supported members. i) Clause 21 on special provisions for seismic design has a number of significant changes. This Clause has been reorganized so that all the requirements for ductile frames are in Clause 21.3, while all the requirements for moderately ductile frames are in Clause 21.4. New dimensional limitations for moderately ductile moment-resisting frames have been added in Clause 21.4.2. The requirements 17 for moderately ductile shear walls have been spelled out in greater detail, and because of the significant overlap with the requirements for ductile shear walls, the requirements for moderately ductile and ductile shear walls are presented together in Clause 21.5. All shear wall design requirements that were redundant with Clause 14 have been removed from Clause 21. Thus, the designer of seismic shear walls must look to Clause 14 for important requirements such as dimensional limitations, transfer of forces across construction joints, and many other requirements. The requirements for strength and ductility over the height of shear walls in Clause 21.5.2 have been expanded. New requirements have been added for the design for bending moment and shear force below the plastic hinge at the base, and for the increased shear force in walls due to the inelastic effects of higher modes. New requirements have been added in Clause 21.5.5 for the anchorage of horizontal reinforcement at the ends of walls depending on the level of ductility. New requirements have been added in Clause 21.5.7 to ensure that walls have adequate ductility to tolerate some yielding near mid-height due to higher mode bending moments. The design requirements for two new types of reinforced concrete SFRS - moderately ductile coupled walls and moderately ductile partially coupled walls - have been added in Clause 21.5.8. The requirements for squat shear walls in Clause 21.5.10 have been relaxed where the walls are longer than needed. The requirements for conventional construction shear walls in Clause 21.6.3 have been expanded. New requirements for the design and detailing of tilt-up construction, including moderately ductile and limited ductility tilt-up walls and frames, are presented in Clause 21.7. New requirements for the design of foundations are presented in Clause 21.10, including the requirement to consider foundation movements. New requirements are presented in Clause 21.11 to ensure that all members not considered part of the seismic-force-resisting system have adequate displacement capacity. j) Clause 23.2.9 provides revised design provisions for structural integrity of tilt-up construction. The effective area of reinforcement used to calculate the factored resisting moment has been modified. k) Annex D on anchorage has been modified to include changes to the requirements specified in Appendix D of ACI 318M-11/318RM-11, Building Code Requirements for Structural Concrete and Commentary. Annex D provides new provisions for the bond strength of adhesive anchors in tension; installation of horizontal and upwardly inclined adhesive anchors; the bond strength of adhesive anchors in tension; the resistance of anchors for load cases involving earthquake effects; revised breakout resistance in shear for an anchor in cracked concrete; and new requirements for the installation of anchors."--Publisher.

Sets out basic theory for the behavior of reinforced concrete structural elements and structures in considerable depth. Emphasizes behavior at the ultimate load, and, in particular, aspects of the seismic design of reinforced concrete structures. Based on American practice, but also examines European practice.
A Complete Guide to Solving Lateral Load Path Problems The Analysis of Irregular Shaped Structures: Diaphragms and Shear Walls explains how to calculate the forces to be transferred across multiple discontinuities and reflect the design requirements on construction documents. Step-by-step examples offer progressive coverage, from basic to very advanced illustrations of load paths in complicated structures. The book is based on the 2009 International Building Code, ASCE/SEI 7-05, the 2005 Edition of the National Design Specification for Wood Construction, and the 2008 Edition of the Special Design Provisions for Wind and Seismic (SDPWS-08). COVERAGE INCLUDES: Code sections and analysis Diaphragm basics Diaphragms with end horizontal offsets Diaphragms with intermediate offsets Diaphragms with openings Open front and cantilever diaphragms Diaphragms with vertical offsets Complex diaphragms with combined openings and offsets Standard shear walls Shear walls with openings Discontinous shear walls Horizontally offset shear walls The portal frame Rigid moment-resisting frame walls--the frame method of analysis
An exploration of the world of concrete as it applies to the construction of buildings, Reinforced Concrete Design of Tall Buildings provides a practical perspective on all aspects of reinforced concrete used in the design of structures, with particular focus on tall and ultra-tall buildings. Written by Dr. Bungale S. Taranath, this work explains the fundamental principles and state-of-the-art technologies required to build vertical structures as sound as they are eloquent. Dozens of cases studies of tall buildings throughout the world, many designed by Dr. Taranath, provide in-depth insight on why and how specific structural system choices are made. The book bridges the gap between two approaches: one based on intuitive skills and experience and the other based on computer skills and analytical techniques. Examining the results when experiential intuition marries unfathomable precision, this book discusses: The latest building codes, including ASCE/SEI 7-05, IBC-06/09, ACI 318-05/08, and ASCE/SEI 41-06 Recent developments in studies of seismic vulnerability and retrofit design Earthquake hazard mitigation technology, including seismic base isolation, passive energy dissipation, and damping systems Lateral bracing concepts and gravity-resisting systems Performance based design trends Dynamic response spectrum and equivalent lateral load procedures Using realistic examples throughout, Dr. Taranath shows how to create sound, cost-efficient high rise structures. His lucid and thorough explanations provide the tools required to derive systems that gracefully resist the battering forces of nature while addressing the specific needs of building owners, developers, and architects. The book is packed with broad-ranging material from fundamental principles to the state-of-the-art technologies and includes techniques thoroughly developed to be

highly adaptable. Offering complete guidance, instructive examples, and color illustrations, the author develops several approaches for designing tall buildings. He demonstrates the benefits of blending imaginative problem solving and rational analysis for creating better structural systems.

"The objective of this research project is to investigate the inelastic behavior and hysteresis rules of low-rise RC perforated shear walls through a series of experimental and analytical studies based on various types of monotonic and earthquake loads. The results derived are then applied to seismic response analysis of box type structures as well as typical low-rise shear wall buildings. The studies also involve development of backbone curves of load-displacement relationship of individual walls, equivalent viscous damping of the walls, and sensitivity analysis of design paramenters for building systems. By observing the failure of cracked shear wall experimentally, a set of semi-empirical equations for backbone curve of perforated shear wall is obtained. Comparison between experimental results and calculated curves is favorable. Concept of energy dissipation is used to establish hysteresis rules which are based on dissipated energy envelopes calculated from experimental data for different loading states. Analytical formulation for a perforated shear wall element model is developed by using three springs: one nonlinear equivalent shear spring; two nonlinear axial springs. Total lateral displacement of a shear wall is a result of both flexure and shear. A four-story industrial building of box type consisting of solid shear walls without boundary columns and a three-story commercial building consisting of isolated columns as well as walls with boundary columns are studied for evaluating various design parameters in building code by using monotonic static analysis. The three-story building is also studied on the basis of dynamic analysis with Lorna Prieta earthquake (1989) and six simulated earthquakes. The sensitivity study of design parameters includes ductility reduction factor, force reduction factor, overstrength factor, and ratio of displacement amplification to force reduction factor. Results are recommended for future building code development"--Abstract, leaf iii.

Solid design and craftsmanship are a necessity for structures and infrastructures that must stand up to natural disasters on a regular basis. Continuous research developments in the engineering field are imperative for sustaining buildings against the threat of earthquakes and other natural disasters. Performance-Based Seismic Design of Concrete Structures and Infrastructures is an informative reference source on all the latest trends and emerging data associated with structural design. Highlighting key topics such as seismic assessments, shear wall structures, and infrastructure resilience, this is an ideal resource for all academicians, students, professionals, and researchers that are seeking new knowledge on the best methods and techniques for designing solid structural designs.

ANSI / AWC SDPWS-2015 - Special Design Provisions for Wind and Seismic standard provides criteria for proportioning, designing, and detailing engineered wood systems, members, and connections in lateral force resisting systems. Engineered design of wood structures to resist wind or seismic forces is either by allowable stress design (ASD) or load and resistance factor design (LRFD). Nominal shear capacities of diaphragms and shear walls are provided for reference assemblies.

This SEAOC Blue Book: Seismic Design Recommendations is the premier publication of the SEAOC Seismology Committee. The name Blue Book is renowned worldwide among engineers, researchers, and building officials. Since 1959, the SEAOC Blue Book, previously titled Recommended Lateral Force Requirements and Commentary, has been a prescient publication of earthquake engineering. The Blue Book has been at the vanguard of earthquake engineering in California and around the world. This edition of the Blue Books offers a series of articles, that cover specific topics, some related to a particular code provision and some more general relating to an area of practice. While different than the previous editions of the Blue Books, it builds upon the tremendous effort of those who have forged earthquake engineering practice via the previous half-century of Blue Book editions. The Blue Book provides: insight and discussion of earthquake engineering concepts; interpretations of sometimes ambiguous or conflicting provisions of various codes, standards, and guidelines; and practical guidance on design implementation.

Forty scientists working in 13 different countries detail in this work the most recent advances in seismic design and performance assessment of reinforced concrete buildings. It is a valuable contribution in the mitigation of natural disasters.

Introductory technical guidance for civil and structural engineers interested in design of buildings to resist seismic forces. Here is what is discussed: 1. INTRODUCTION 2 DESIGN FORCES 3. WALL COMPONENTS 4. IN-PLANE EFFECTS 5. OUT-OF-PLANE EFFECTS 6. CAST-IN-PLACE CONCRETE SHEAR WALLS 7. MASONRY SHEAR WALLS 8. WOOD STUD SHEAR WALLS 9. STEEL STUD SHEAR WALLS.

This thesis is the second stage of the shear wall project, and it focuses on numerical investigations of HMEs on structural wall responses. The thesis consists of three main phases, and each phase corresponds to one (available online or submitted) journal paper. The first two phases were restricted to isolated and two-dimensional RC shear wall models without considering cross-sectional torsional effect and interactions between different shear walls. On the other hand, the last phase investigated three-dimensional RC shear walls in the context of an existing building.

This volume consists of papers presented at the International Workshop on Concrete Shear in Earthquake, held at the University of Houston, Texas, USA, 13-16 January 1991.

Design of Reinforced Concrete, 10th Edition by Jack McCormac and Russell Brown, introduces the fundamentals of reinforced concrete design in a clear and comprehensive manner and grounded in the basic principles of mechanics of solids. Students build on their understanding of basic mechanics to learn new concepts such as compressive stress and strain in concrete, while applying current ACI Code.

This book comprises selected proceedings of the International Conference on Recent Advancements in Civil Engineering and Infrastructural Developments (ICRACEID 2019). The contents are broadly divided into five areas (i) smart transportation with urban planning, (ii) clean energy and environment, (iii) water distribution and waste management, (iv) smart materials and structures, and (v) disaster management. The book aims to provide solutions to global challenges using innovative and emerging technologies covering various fields of civil engineering. The major topics covered include urban planning, transportation, water distribution, waste management, disaster management, environmental pollution and control, environmental impact assessment, application of GIS and remote sensing, and structural analysis and design. Given the range of topics discussed, the book will be beneficial for students, researchers as well industry professionals.

Reinforced concrete shear walls are commonly used to provide lateral strength and stiffness to concrete buildings in seismic regions. Typically installed in the wall face, mechanical anchors are responsible for connecting various nonstructural systems to the main structure. During an earthquake, anchors in reinforced concrete structural elements need to retain their strength and stiffness, despite the inevitable presence of cracks and damage in the concrete, developed as a consequence of the lateral cyclic loading. Anticipating damage to the concrete, which will naturally influence anchor response, current guidelines to qualify anchors for seismic applications require adequate performance in cracked concrete to assure minimal anchor load loss. However, these guidelines are based on anchor performance in pure flexural cracks, as this is the typical damage condition occurring in reinforced concrete frame elements, which has been studied for decades. The response of anchors to a mix of flexure and shear cracks, i.e., the complex situation realized in shear-flexure structural components such as shear walls, however, has largely not been studied. To address the paucity of data regarding anchor behavior in cracked concrete, the behavior of anchors installed horizontally in three full-scale reinforced concrete shear walls with different aspect ratios (wall height/length) is studied in this dissertation. Notably, two types of post-installed anchors were investigated in these tests, namely: i) expansion anchors and ii) bonded anchors. One slender and two identical low-aspect ratio walls were designed according to current U.S. design codes. Simulated seismic loading was imposed at the top of the wall using an equivalent cyclic displacement history, while uniform compression was applied on the slender and one of the two identical low-aspect ratio shear walls. One of the low aspect ratio walls was tested without axial compression to investigate its effect on the anchor response. Anchors were continuously loaded to their design tension while the walls were cycled. The slender full-scale wall failed in a predominantly flexural mode, precipitated by buckling and fracture of the boundary reinforcement. The two identical full-scale low-aspect ratio walls failed in a mixed flexure-shear response, with severe web concrete crushing and buckling and rupture of the boundary reinforcement. Anchor axial load and displacement data, continually measured during the wall cyclic tests, confirmed the sensitivity of the performance of anchors amidst the presence of a variety of cracked concrete conditions, especially in walls prone to develop large shear stress and shear induced damage when subjected to lateral cyclic loads. Following the wall cyclic tests, tension failure tests performed on the anchors indicated that their residual tension load capacity was significantly compromised by concrete damage. Such damage was concentrated in specific wall regions, such as the boundary elements and the plastic hinge region in slender walls, or along the diagonal struts, the boundary elements and near the base of low-aspect ratio walls. Of the two types of anchors tested, expansion anchors observed the most significant load loss (and consequentially axial displacement) in the presence of both the wall cyclic loading and the residual tests on the anchors themselves. Following the experimental program, a multiple vertical line finite element model was used to predict the response of each of the tested full-scale shear walls. Numerical analyses cross-comparison with test results demonstrated a high level of accuracy of the selected modeling approach. As such, an expanded parametric study was conducted to understand the extent of severe concrete strains on the crack distribution and width, using a smeared crack approach. Wall models designed for the parametric study were intended to explore different geometry, reinforcement and axial compression to study the damage distribution within the wall elevation. Crack pattern distribution plots developed using the parametric study results were used to identify regions where anchors would be vulnerable to load loss upon achievement of service, design and severe seismic damage. Ultimately, the findings from this dissertation shed light on the vulnerability of anchors placed in reinforced concrete shear walls, where damage in the form of mixed mode cracking and spalling can be expected. Future design guidelines would benefit from precluding crack sensitive anchors in the most highly damaged regions of these essential lateral force resisting components of the structural system.