Concrete Shear Wall Design

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Behavior of Post-installed Anchors in Reinforced Concrete Shear Walls of Different Aspect Ratios Subjected to Simulated Seismic Loads American Concrete Institute
Concrete shear walls are used as the seismic force resisting system in many high-rise buildings in Western Canada. During earthquake, the response of a high-rise concrete wall as it undergoes severe cracking of concrete and yielding of reinforcement is very complex. In particular, the nonlinear shear behaviour of concrete shear walls is not well known; therefore available analysis programs generally use very primitive models for nonlinear shear behaviour. Gérin and Adebar (2004) quantified the observed experimental results on reinforced concrete membrane elements and presented a simple nonlinear shear model that included the influence of concrete diagonal cracking, yielding of horizontal reinforcement and ultimate shear capacity. There are a number of important issues in the design of high-rise concrete shear walls where shear deformations play a very important role and hence nonlinear shear behaviour will have a significant influence. In this dissertation, three different seismic design issues where nonlinear shear response plays a significant role are investigated. The first issue which is of considerable concern to designers is the large reverse shear force in high-rise concrete walls due to rigid diaphragms below the flexural plastic hinge. The nonlinear analyses that were carried out in this study show that diagonal cracking and yielding of horizontal reinforcement significantly reduce the magnitude of reverse shear force compared to what is predicted by using linear analysis procedures. A second issue where nonlinear shear behaviour has a significant influence is associated with the shear force distribution between inter-connected high-rise walls of different lengths. The results presented in this work, show that when diagonal cracking is included in the analysis, significant redistribution of shear forces takes place between walls and all walls do not necessarily yield at the same displacement. The third issue is related to the dynamic shear demand caused by.
Advances in Civil Engineering and Infrastructural Development Mississauga, Ont. : Canadian Standards Association
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.
Building Code Requirements for Structural Concrete (ACI 318-08) and Commentary Seismic Design Factors for Precast Concrete Shear Wall StructuresBuilding Code Requirements for Structural Concrete (ACI 318-05) and Commentary (ACI 318R-05)
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.
Interactive Analysis and Design of Reinforced Concrete Frame-shear Wall Buildings Guyer Partners
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.
John Wiley & Sons
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.
Seismic Response Assessment of Thin Boundary Elements of Special Concrete Shear Walls FEMA
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.
Theory and Design CRC Press
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.

Design of Reinforced Concrete, 10th Edition John Wiley & Sons

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.

fib Model Code for Concrete Structures 2010 Wiley Global Education

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

Displacement-based Seismic Design of Reinforced Concrete Shear Wall Buildings IGI Global

This book focuses on the analysis and design of reinforced concrete structural members in conformity with the 2014 version of the CSA A23.3 Canadian standard. Such members are often encountered in practice, particularly in buildings. This second edition considers all the changes brought into the 2014 CSA A23.3 Canadian standard. In addition, with respect to the first edition, two new chapters related to the design of walls and of prestressed concrete structures are introduced. Using an original approach, the author presents the subject matter as clearly and effectively as possible. Each aspect is carefully illustrated and is the subject of a thorough theoretical development. This is followed by a step-by-step procedure for both design and verification, along with many fully developed numerical applications.This book is intended for practicing engineers as well as for students of that field. Engineers will find a valuable and concise reference which complements the standards and other engineering tools for their daily tasks. Students will use it as a textbook on reinforced concrete structures presented in an original and easy-to-use format.

Select Proceedings of ICRACEID 2019 Amer Society of Civil Engineers

Seismic Design Factors for Precast Concrete Shear Wall StructuresBuilding Code Requirements for Structural Concrete (ACI 318-05) and Commentary (ACI 318R-05)American Concrete InstituteHysteresis Rules of Perforated Low-rise Reinforced Concrete Shear Walls and Seismic Design Parameters Assessment of Buildings

Reinforced Concrete Structures National Library of Canada = Bibliothèque nationale du Canada

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.

John Wiley & Sons

"This report investigates the failure mechanisms of shear-critical squat (ration height to length of less than two) reinforced concrete walls, commonly used in many commercial buildings and nearly all safety-related nuclear structures. A database with experimental data obtained from 434 tests is assembled with the objective of improving the current state of knowledge on squat wall response. The adequateness of the peak shear strength predictive equations available in current design provisions is evaluated. Improved empirical equations are developed for peak shear strength prediction for rectangular walls and walls with boundary elements in a format suitable for inclusion in standards and codes of practice. Squat walls are modeled using finite elements to predict their monotonic and cyclic responses. Modeling decisions that are critical to predict the wall responses are explored and recommendations for finite element modeling are made. Macro-level hysteretic models are prepared for a small number of squat walls for which digital load-displacement data are available. The calibrated Ibarra-Krawinkler pinching model is used to properly capture the strength, stiffness degradation and pinching effects in the walls response. Information in the database is used to identify damage states and to develop fragility functions for buildings and safety-related nuclear structures incorporating squat reinforced concrete walls"--Page iv.

NEHRP Recommenede Provisions: Design Examples American Concrete Institute

Past earthquakes have shown examples of unsatisfactory performance of buildings using reinforced concrete structural walls as the primary lateral-force-resisting system. In the 1994 Northridge earthquake, examples can be found where walls possessed too much overstrength, leading to unintended failure of collectors and floor systems, including precast and post-tensioned construction. In the 2010 Maule Chile earthquake, many structural wall buildings sustained severe damage. Although Chilean design standards result in different reinforcement detailing than is common in U.S. walls, the failure patterns raise concerns about how well conventionally reinforced structural walls in U.S. buildings will perform during the next earthquake. Alternative wall design philosophies that offer more predictable response, with better damage control, should be investigated. After the Mw 8.8 Chile earthquake, the 15-story Alto Rio building in Concepción sustained failures near the base, overturned, and came to rest on its side. The collapse of the Alto Rio building was significant because it was designed using the Chilean Building Code NCh433. Of96, which requires the use of ACI 318-95 for design of reinforced concrete structural elements intended to resist design seismic forces. The failure of the Alto Rio building is significant for many reasons. It is the first modern shear wall building of its type to collapse by overturning during an earthquake. The building is studied using forensic data and structural models of the framing system subjected to earthquake shaking. The study identifies the likely failure mechanism and suggests areas for which design and detailing practices could be improved. The capabilities and shortcomings of the analyses to identify details of the failure mechanism are themselves important outcomes of the study. A second study explores the behavior of structural wall buildings using unbonded post-tensioned structural walls. Such walls offer the opportunity to better control yielding mechanisms and promote self-centering behavior. The study focuses on the measured responses of a full-scale, four-story building model tested on the E-Defense shaking table in Japan. The seismic force-resisting system of the test building comprised two post-tensioned (PT) precast frames in one direction and two unbonded PT precast walls in the other direction. The building was designed using the latest code requirements and design recommendations available both in Japan and the U.S., including the ACI ITG-5.2-09. The test building was subjected to several earthquake ground motions, ranging from serviceability level to near collapse. Analytical studies were carried out to test the capability of the structural models to replicate behaviors important to structural engineers, and to assess whether available analysis tools are sufficient to model dynamic behavior that results when a full-scale building is subjected to realistic earthquake ground shaking. Measured response data from such an outstanding test provides an opportunity to fully understand the response characteristics of PT walls and assess the ability of nonlinear analytical models to reproduce important global and local responses, including three-dimensional system interactions, both prior to and after loss of significant lateral strength. Moreover, this study to assess behavior and system interaction of PT walls leads to improvements of the current design ideas and performance expectations. The present study examines both the collapse of the Alto Rio building in Chile and the shaking table tests of the unbonded post-tensioned wall building in Japan. The collapse study suggests areas of improvement in current design and detailing practice. The shaking table study suggests an alternative approach to design of shear walls in buildings. Both studies demonstrate the use of modern structural analysis tools to interpret building responses to earthquake shaking. Taken together, the studies provide added confidence in earthquake simulation capabilities and demonstrate alternatives for designing earthquake-resistant buildings that use structural walls.

Frame-shear Wall Structures in Tall Building Springer Nature

Damage observed near the base of shear walls of reinforced concrete buildings after the Chile (2010) and New Zealand (2011) earthquakes are signs of shortcomings in the design of walls that need to be addressed. This investigation presents results of an experimental test program on ten reinforced concrete rectangular prisms representative of the flexural compression zone of flanged shear walls. The tested elements have transverse reinforcement detailing that matches or exceeds modern code requirements for special boundary elements. The main test variables were the amount and spacing (both vertical and horizontal) of the hoop and crosstie reinforcement. The elements were subjected to monotonically increasing axial compression until failure. Effects of strain gradient (both through the wall length and along the wall height) and effects of wall shear are not represented in the present tests. Nonetheless, the axial compression tests provide insights into the behavioral characteristics of actual wall boundaries. The global force shortening behavior of the specimens was commanded by a thin core which integrity was heavily compromised due to cover spalling, rebar buckling and out-of-plane instability. Measured load-displacement relations did not exhibit an acceptable ductile behavior suggesting that current building code requirements for special boundary elements do not necessarily achieve effective confinement to be protected against brittle axial failure. Enhanced detailing (increasing the volumetric ratio of confinement reinforcement and decreasing its horizontal spacing) improved behavior but did not produce ductile response in all cases. Reported damage extension concentrated over length corresponding to two-and-half times the thickness of the specimens. Compressive strain limits for stable behavior are proposed to be function of the gage length over which they are measured. Bar buckling reduced the load carrying capacity of the reinforced concrete prisms because of the strength loss suffered by the longitudinal reinforcement, but also because it prevented the effective confinement of the concrete core. An experimental campaign comprising 48 analytical specimens allowed studying the relationship between tie spacing and stiffness, and the diameter of the longitudinal bars, that influenced their response when undergoing lateral instability (inelastic buckling). The behavior of tied bars undergoing lateral instability in the inelastic range is highly influenced by the relative restrictive tie spacing over which bar buckling is forced into, and the relative stiffness of the transverse ties and the longitudinal bar. The experiments assume a rigid contact between the bar and the tie, therefore hook opening is not modeled. For the range of tie stiffness and bar geometries tested, the results indicate that the tie spacing has to be smaller than 4.5 times the bar diameter to prevent bar buckling over a large range of plastic axial strains. Empirical core stress strain curves, accounting for bar buckling, are reported for point wise strain measurements, as well as for average axial strains recorded within the damaged region. The results show that usable strain limits, to guarantee a stable core response in pure compression, are between 1.1 and 2.0%. Average empirical core stress strain curves are proposed for modeling purposes. Implication of the compressive strain limits observed are evaluated in a hazard-consistent manner by means of the Conditional Scenario Spectra (CSS). The CSS is a set of realistic earthquake spectra with assigned rates of occurrence that reproduce the hazard at a site. Structural responses are obtained by means of numerical analysis of a multistory shear wall under the seismic demand of more than eight-hundred ground motions consistent with the CSS. The case study allows estimating risk curves to evaluate the likelihood of exceeding certain threshold compressive strains in the boundary of the cross section. The single case numerical model showed that the limited strain capacity of these elements is only likely to negatively impact the behavior of the wall system at risk levels beyond the code-based expectations of good behavior.

Hysteresis Rules of Perforated Low-rise Reinforced Concrete Shear Walls and Seismic Design Parameters Assessment of Buildings

"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.

Seismic Design Recommendations

Reinforced concrete shear walls as seismic force resisting systems may experience inelastic deformations if subjected to strong seismic excitations. These walls are designed to provide strength, stiffness, energy dissipation capacity and lateral drift control for seismic resistance. Shear wall deformability is largely dependent on adequate confinement of core concrete in boundary elements, prevention of longitudinal bar buckling, as well as proper design and detailing of the web section. Conventional transverse reinforcement placed in shear wall boundary elements consists of hoops, overlapping hoops and crossties, based on the geometry and number of longitudinal bars used. The confinement steel requirement of current building codes (ACI 318 or CSA A23.3) often results in congestion of steel cage due to the high transverse reinforcement ratio required. Placing multiple hoops with 135-degree bends combined with crossties to satisfy the code confinement requirements can create concrete placement and construction problems. In addition, the required time to assemble conventional steel cages with multiple individual ties per spacing can be time consuming, potentially impacting the overall cost and duration of construction. Welded Wire Reinforcement (WWR) is available in the construction industry as concrete reinforcement in the form of welded wire fabric (WWF) manufactured from relatively small diameter wires in comparison to the bar sizes typically used in structural applications. As an alternative to using conventional transverse hoops, prefabricated WWR grids can be used to provide required transverse reinforcement in boundary elements. WWR grids are manufactured using robots to weld cut steel pieces accurately before they are shipped to the job site, resulting in better construction quality and reduced construction time. However, research on the use of WWR is limited in the literature. Further experimental and analytical research is needed to establish design requirements for such reinforcement, especially when used in earthquake resistant construction with requirements for ductile response. The current research project, involved three main phases; i) tests of 3 large-scale reinforced concrete shear walls with WWR grids used as boundary element transverse reinforcement, ii) material tests of grid samples, including those cast in concrete, iii) non-linear finite element analysis. The wall tests were conducted under slowly-applied lateral deformation reversals to investigate their strength and ductility for suitability as seismic resistant structural elements. Material tests were conducted to have a better understanding of WWR behavior, especially their weld capacity. Analytical research was undertaken to expand the experimental findings on shear wall behavior, as well as to conduct parametric investigation to understand the impact of changes in grid strength and ductility. The results indicated that WWR grids can be used as boundary element transverse reinforcement in earthquake resistant shear wall. However, strength and ductility of grids should be established carefully prior to such application. Design strength of WWR grids should be established through burst tests to ensure ductile yielding of wire reinforcement prior to premature weld failure. Those grids that exhibit weld failures may be used with reduced design strength to permit the development of sufficient inelastic deformability in flexure-dominant shear walls.

Seismic Design for Buildings

Seven high strength concrete shear walls identified as HSCWl to HSCW7 were built and tested in a rig specially built for that purpose. Main variables of the study were axial load, strength of the concrete, horizontal and vertical steel ratios. The shear wall panels had a thickness of 75 mm, with a length of 700 mm and a height of 1100 mm. The dimensions of edge columns were 375 mm x 90 mm with the height of 1100 mm. All specimens were designed to fail in shear. Computer software capable of estimating ultimate load and displacements of a shear wall specimen subjected to constant axial load and monotonically increasing lateral load is presented. Smeared crack model along with smeared reinforcement assumption were used in a non-linear finite element analysis taking into account tension softening and tension stiffening as well as compression softening in the concrete due to tensile stresses in the other directions. Correlation of tests and predicted loaddisplacement graphs are discussed. A number of specimens tested by other researchers were also analysed and compared with experimental results. The effects of the main variables of the tests on the shear strength of walls are presented and the computer Simulator is used to undertake parametric studies on a wide range of prototype shear wall specimens. The pool of experimental results for 75 test specimens is used to compare the accuracy and safety of design equations proposed by major codes.

Minimum Design Loads for Buildings and Other Structures

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.

Seismic Shear Demand in High-rise Concrete Walls

The report considers the economic feasibility of using metallic interior shear wall elements in place of conventional reinforced concrete shear wall elements in hardened facilities. A simplified, aboveground two story building is designed using both conventional concrete and metallic shear wall elements. Five combinations of weapon yield and overpressure are used to size the building elements. Three wall configurations are considered: reinforced concrete, low yield strength steel (A-36), and high yield strength steel (A-514). Total facility and shear wall costs are compared. Based upon a somewhat limited use of metallic materials, it is nonetheless clearly indicated that the use of metallic interior shear walls can substantially reduce facility structural costs by as much as nine percent at low overpressures. Comparing the in-place wall costs, savings on the order of 50 percent are possible under some design requirements and metallic material properties. (Author).