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Base Plate and Anchor Rod Design

Column Base Plates *Amer Inst of Steel Construction*

Behavior of Exposed Column Base Plate Connection Subjected to Combined Axial Load and Biaxial Bending

Column base plate (CBP) connections are one of the most crucial structural components of steel structures that act as a transfer medium for all the forces and moments from the entire building into the foundation. Importance of this type of connection becomes significant when the structure experiences dynamic loading, such as wind or earthquake, which incorporates dynamic effects in the structure that need to be transferred to the foundation. Considerable research efforts have been made over the past few decades on CBP connections, which led to the publication of AISC Design Guide 1 (2006) for CBP design. This design guide is still widely used in the industry. All the previous studies and design guidelines considered only the uniaxial (major axis) bending moment combined with axial load for CBP connection design. However, very often the base plate experiences a bidirectional bending moment from lateral loads during any dynamic loading event. Although, the column is designed and checked under combined axial load and bi-axial bending, when it comes to the base plate connection, only the axial load and major axis bending are considered. Therefore, the objective of this research is to investigate the behavior of CBP connections subjected to combined axial load and biaxial bending through an extensive numerical parametric study, using general purpose finite element software ABAQUS. For this numerical study, an accurate nonlinear finite element (FE) model is developed, considering both geometric and material nonlinearities and validated against experimental results that are available in the literature subjected to monotonic and uniaxial cyclic loading. Validation results show that the developed FE model can effectively simulate force transfer at major contact interfaces in the connection. Concurrently, a database of CBP connection subjected to axial load and uniaxial bending, is constructed from the literature to identify the influential parameters as well as different failure modes of the CBP connection, using Machine Learning (ML) approach. Among nine different ML models, the Decision tree based ML model provides an overall accuracy of 91% for identifying the failure mode whereas base plate thickness, embedment length, and anchor rod diameter are found to be the influential parameters that govern the failure mode of CBP connections. Therefore, a total of 20 different FE models that have different base plate thicknesses and yield strengths, anchor bolt sizes and quantity as well as embedment lengths, grout thicknesses and axial load ratios are developed. Furthermore, a bidirectional symmetric lateral loading protocol is developed and applied with constant axial compressive load in the developed models. The study reveals that the thickness of base plate and anchor rod diameter are the governing parameters for different base connection behavior such as moment rotation response, maximum bolt tensile force, and yield line pattern of the base plate. Moreover, the rigidity of the base plate connection is found to be in the semi-rigid region under biaxial bending condition. Finally, this study found that the available methods for uniaxial bending overpredicts the connection rotational stiffness compared to the stiffness obtained from numerical analysis considering biaxial bending.

Wind Loads and Anchor Bolt Design for Petrochemical Facilities *ASCE Publications*

Prepared by the Task Committee on Wind-Induced Forces and Task Committee on Anchor Bolt Design of the Petrochemical Committee of the Energy Division of ASCE. This report presents state-of-the-practice set of guidelines for the determination of wind-induced forces and the design of anchor bolts for petrochemical facilities. Current codes and standards do not address many of the structures found in the petrochemical industry. As a result, engineers and petrochemical companies have independently developed procedures and techniques for handling engineering issues such as the two contained in this report. A lack of standardization in the industry has led to inconsistent structural reliability, however. This volume is intended for structural design engineers familiar with design of industrial-type structures.

Finite Element Simulations of Exposed Column Base Plate Connections Subjected to Axial Compression and Flexure

Exposed column base plate connections are crucial components in earthquake-resistant steel structures, but previous research has produced a limited quantitative understanding of its load transfer mechanisms. Recently, a large-scale experimental program was performed at the University of California at Davis to achieve a fundamental understanding of the base connection response under axial compression and strong-axis bending. The study described in this Thesis complements the experimental program and consists of two series of finite element simulations conducted to: (1) develop a validated approach for simulation of exposed column base connections and (2) to perform an analytical parametric study using the validated approach to generalize the findings of the experimental program to untested situations. The parameters scrutinized in the numerical study are anchor rod grade and configuration, base plate size and thickness, column size, magnitude of axial load, and the direction of lateral load. The FEM models were validated by comparing the analytical results against various experimental observations (e.g. the load deformation curve, and measurements of anchor rod strains). The finite element simulations reproduced the experimental results and produced new findings. The simulations were determined to appropriately simulate deformation (and failure) modes (i.e. deformed base plate shape, anchor rod yield, etc.), and the excellent ductility of the base connections (i.e. excess of 6% drift capacity). The "thin" base plates displayed more ductility compared to "thick" base plates. The bearing stress distribution gets concentrated underneath the column flange (e.g. compression region), and it varies depending on the base plate thickness. Contrary to current design considerations, inclined and straight yield line patterns developed on the tension and compression region of the base plate, as well as on the sides of the plate, depending on the base plate footprint and thickness. In addition, two base connections with realistic, first-story column sizes were tested to observe their response. It was discovered that a substantially "thick" base plate develops most of its yield lines on the tension region of the plate, caused by the large prying anchor rod forces.

Techniques for the Seismic Rehabilitation of Existing Buildings *FEMA*

Illustrated in full color throughout. The primary purpose of this document is to provide a selected compilation of seismic rehabilitation techniques that are practical and effective. The descriptions of techniques include detailing and constructability tips that might not be otherwise available to engineering offices or individual structural engineers who have limited experience in

seismic rehabilitation of existing buildings. A secondary purpose is to provide guidance on which techniques are commonly used to mitigate specific seismic deficiencies in various model building types.

Steel Strength of Anchor Bolts in Stand-Off Base Plate Connections

Connections exposed to generalized loading and exposed length conditions. The models were governed by the interaction of normal force, shear force, and bending moment on the circular anchor bolt cross-section and, for grouted connections, the influence of interfacial friction. Simplified recommendations were provided for practical implementation of the findings presented within this dissertation.

Moment-rotation Behavior of Base-plate Connections in Low-rise Metal Buildings

In designing low-rise metal building systems, column-base connections are commonly assumed to be pinned with no rotational stiffness for both serviceability and strength limit states; however, practical experience indicates that even base connections that are designed to be pinned have a non-negligible rotational stiffness. The excess displacement resulting from this assumption is addressed by increasing the flexural stiffness of the frame members, which unnecessarily increases the cost of low-rise metal buildings. There is a distinct lack of design guidelines and experimental data to support the use of non-zero rotational stiffness at the so-called pinned column bases. The objective of this research is to quantify the rotational stiffness as well as the strength of column base-plate connections in low-rise metal building systems by testing eight full-scale base-plate connections with varying base-plate dimensions, number of anchor rods, anchor rod diameters and gage distances, and taper of the column sections.

The Behavior of Thin Hollow Structural Section (HSS) to Plate Connections

Tightening Procedures for Large-diameter Anchor Bolts

Recent failures of cantilever overhead sign structures in Michigan and elsewhere, coupled with the absence of standards for tightening methods for the double-nut system used with large-diameter anchor bolts in similar structures in Texas have been the motivation for this study. Practices of various field offices were reviewed, a literature study was performed, and both laboratory studies and field studies were performed. Three questions were raised: How tight do the anchor bolt nuts need to be? What techniques and procedures are best suited for tightening? How can tightness best be inspected? Standards for tightening procedures for large-diameter anchor bolts are proposed. In current TxDOT practice, the contractor is left to his or her own judgment concerning how tight to tighten the nuts on the double-nut anchor bolt system. Recent bolt failures in other states have raised concerns about nut tightening procedures. When the nuts of a double-nut system are not tightened sufficiently, fatigue loading, and even impact loading, can be factors in the performance of the bolts. Three full-size test specimens were built in the laboratory to evaluate tightening methods and the fatigue performance of the double-nut system used for anchorage of cantilever overhead sign structures (COSS) and on high mast illumination poles (HMIP). Analytical and numerical studies were performed to identify and study parameters affecting the stresses in the anchor bolts. Field studies were conducted to measure the wind-load induced anchor bolt reactions and stresses in one specimen of each type. This

report details these studies and the findings.

Determining the Validity of Design Provisions for HSS to Base Plate Connections with Corner Anchor Rods Subjected to Axial Tension

Experimental data and calculations showed that the elimination of a factor leftover from an error in the derivation of the equation, along with the addition of an HSS factor, $R_{sub\ hss}$, produces comparable results for corner plate stress. The adjusted equation is: (equation). Weld results were inconclusive, but results are discussed. Contributing weld length should be further examined. Research focused on weld behavior is recommended.

Design of Skirt, Anchor Bolts and Base Plate

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Challenges, Opportunities and Solutions in Structural Engineering and Construction *CRC Press*

Challenges, Opportunities and Solutions in Structural Engineering and Construction addresses the latest developments in innovative and integrative technologies and solutions in structural engineering and construction, including: Concrete, masonry, steel and composite structures; Dynamic impact and earthquake engineering; Bridges and

Official Gazette of the United States Patent Office

Earthquake Engineer 10th World *Taylor & Francis US*

Structural Analysis of Sign Bridge Structures and Luminaire Supports

Anchor Bolt Position in Base Plate in Term of "T" and "J" Anchor Bolt

Structural Design Guide

To the AISC (LRFD) Specification for Buildings *Springer Science & Business Media*

|| This book is intended to guide practicing structural engineers into more profitable routine designs with the AISC Load and Resistance Factor Design Specification (LRFD) for structural steel buildings. LRFD is a method of proportioning steel structures so that no applicable limit state is exceeded when the structure is subjected to all appropriate factored load combinations. Strength limit states are related to safety, and concern maximum load carrying capacity. Serviceability limit states are related to performance under service load conditions such as deflections. The term "resistance" includes both strength states and serviceability limit states. LRFD is a new approach to the design of structural steel for buildings. It involves explicit consideration of limit states, multiple load factors and resistance factors, and implicit probabilistic determination of reliability. The type of factoring used by LRFD differs from the allowable stress design of Chapters A through M of the 1989 Ninth Edition of the AISC Specifications for Allowable Stress Design, where only the resistance is divided by a factor of safety to obtain an allowable stress, and from the plastic design provisions of Chapter N, where the loads are multiplied by a common load factor of 1.7 for gravity loads and 1.3 for gravity loads acting with wind or seismic loads. LRFD offers the structural engineer greater flexibility, rationality, and economy than the previous 1989 Ninth Edition of the AISC Specifications for Allowable Stress Design.

Standard Specifications for Highway and Structure Construction

Anchor Bolt Position in Base Plate in Terms of Design L and Design T

Structural Steel Drafting and Design *Cengage Learning*

Practical and easy to use, this text lays a solid groundwork for beginning and intermediate students to pursue careers in architecture, construction, or civil engineering. The text clarifies the vital interdependence between structural steel design and fabrication drawings, equipping students to work flexibly with both. First and foremost a drafting book, Structural Steel Drafting and Design gives an overview of structural design theory while providing numerous examples, illustrations, and real-world assignments. Students also become acquainted with critical tables and reference material from industry-standard sources, as well as the merits of Load and Resistance Factor Design and Allowable Strength Design. Important Notice: Media content referenced within the product description or the product text may not be available in the ebook version.

Resilient Structures and Infrastructure *Springer*

This book discusses resilience in terms of structures' and infrastructures' responses to extreme loading conditions. These include static and dynamic loads such as those generated by blasts, terrorist attacks, seismic events, impact loadings, progressive collapse, floods and wind. In the last decade, the concept of resilience and resilient-based structures has increasingly gained in interest among engineers and scientists. Resilience describes a given structure's ability to withstand sudden shocks. In other words, it can be measured by the magnitude of shock that a system can tolerate. This book offers a valuable resource for the development of new engineering practices, codes and regulations, public policy, and investigation reports on resilience, and provides broad and integrated coverage of the effects of dynamic loadings, and of the modeling techniques used to compute the structural response to these loadings.

Behavior and Design of Column Base Connections

This dissertation investigates the design and behavior of column base plate connections, a common structural component used to transfer forces from the steel superstructure to the supporting concrete foundation. Laboratory testing and damage reported in recent earthquakes has demonstrated the susceptibility of these connections to various failure modes. However, compared to other structural connections, column bases have received relatively limited research attention. In order to characterize the connection behavior, results from two series of large-scale testing are presented. The first phase of testing investigates common base connection shear transfer mechanisms, including plate friction, anchor rod bearing and shear key bearing. The second phase of testing investigates the response of exposed bases subjected to axial compression and flexural loading. The test observations are complimented by detailed test analyses and FEM simulations. A detailed review of existing design provisions, design guides and published research reveals that current approaches to characterize the behavior of exposed column base connections loaded in shear or a combination of axial compression and flexure are not well developed nor supported by adequate experimental validation. Thus, the test data is used to evaluate existing approaches and propose refinements. For example, the tests investigating shear key bearing indicate that current strength design provisions may be significantly

unconservative for large foundations due to the size effect in concrete. Furthermore, an evaluation of experimental data indicates that the current design methods for flexural loading may be highly conservative with respect to the ultimate strength of the connection. A design approach is proposed in which the ultimate strength of the connection is governed by the formation of a plastic mechanism. All test specimens show outstanding ductility, suggesting that reliable inelastic action is possible for base plate connections. Additional methods, which are based on the concept of the center-of-rotation of the base plate, are proposed to characterize the anchor rod forces and the initial moment-rotation behavior. The proposed behavior predictions are highly accurate with respect to the test data. The dissertation concludes with a detailed overview of current design provisions along with analysis and recommendations for design.

Guide to the Concrete Capacity Design (CCD) Method

Embedment Design Examples

Foundation and Anchor Design Guide for Metal Building Systems *McGraw Hill Professional*

MEET THE COMPLEX CHALLENGES OF METAL BUILDING SYSTEMS FOUNDATION DESIGN Expand your professional design skills and engineer safe, reliable foundations and anchors for metal building systems. Written by a practicing structural engineer, Foundation and Anchor Design Guide for Metal Building Systems thoroughly covers the entire process--from initial soil investigation through final design and construction. The design of different types of foundations is explained and illustrated with step-by-step examples. The nuts-and-bolts discussion covers the best design and construction practices. This detailed reference book explains how the design of metal building foundations differs from the design of conventional foundations and how to comply with applicable building codes while avoiding common pitfalls. COVERAGE INCLUDES: Metal building and foundation design fundamentals Soil types, properties, and investigation Unique aspects of foundation design for metal building systems Design of isolated column footings Foundation walls and wall footings Tie rods, hairpins, and slab ties Moment-resisting foundations Slab with haunch, trench footings, and mats Deep foundations Anchors in metal building systems Concrete embedments in metal building systems

Pressure Vessel Design Manual *Elsevier*

A pressure vessel is a container that holds a liquid, vapor, or gas at a different pressure other than atmospheric pressure at the same elevation. More specifically in this instance, a pressure vessel is used to 'distill'/'crack' crude material taken from the ground (petroleum, etc.) and output a finer quality product that will eventually become gas, plastics, etc. This book is an accumulation of design procedures, methods, techniques, formulations, and data for use in the design of pressure vessels, their respective parts and equipment. The book has broad applications to chemical, civil and petroleum engineers, who construct, install or operate process facilities, and would also be an invaluable tool for those who inspect the manufacturing of pressure vessels or review designs. * ASME standards and guidelines (such as the method for determining the Minimum Design Metal Temperature) are impenetrable and expensive: avoid both problems with this expert guide. * Visual aids walk the designer through the multifaceted stages of analysis and design. * Includes the latest procedures to use as tools in solving design issues.

Seismic Behavior of Column-base Plate Connections Bending about Weak Axis

Design Of Steel Structures (By Limit State Method As Per Is: 800 2007) *I. K. International Pvt Ltd*

So far working stress method was used for the design of steel structures. Nowadays whole world is going for the limit state method which is more rational. Indian national code IS:800 for the design of steel structures was revised in the year 2007 incorporating limit state method. This book is aimed at training the students in using IS: 800 2007 for designing steel structures by limit state method. The author has explained the provisions of code in simple language and illustrated the design procedure with a large number of problems. It is hoped that all universities will soon adopt design of steel structures as per IS: 2007 and this book will serve as a good textbook. A sincere effort has been made to present design procedure using simple language, neat sketches and solved problems.

Handbook of Machine Foundations *Tata McGraw-Hill Education*

Imperfect designing of machine foundations based on empirical formulations has led to the problem of troublesome vibrations in the existing foundations. Recent developments in the field of structural and soil dynamics have helped establish basic design principles for various types of machine foundations. In order to achieve efficiency and economy in the design, it is imperative that the designer have an in depth knowledge of various aspects of analysis, design and construction of machine foundations

Weld Behavior in a Rectangular HSS Base Plate Connection with Corner Anchor Rods Subjected to an Axial Tensile Force

Official Gazette of the United States Patent and Trademark Office

Report on the Collapse of the KCRG-TV Tower

Steel Frame Design Examples *Macmillan International Higher Education*

Fatigue-resistant Design of Cantilevered Signal, Sign and Light Supports *Transportation Research Board*

Construction Management and Design of Industrial Concrete and Steel Structures *CRC Press*

The recent worldwide boom in industrial construction and the corresponding billions of dollars spent every year in industrial, oil, gas, and petrochemical and power generation project, has created fierce competition for these projects. Strong management and technical competence will bring your projects in on time and on budget. An in-depth explorat

Seismic Behavior of Moment-resisting Steel Column Bases

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Design Of Steel Structure 3E *Tata McGraw-Hill Education*

Steel Construction Manual *Amer Inst of Steel Construction*

Originally published in 1926 [i.e. 1927] under title: Steel

construction; title of 8th ed.: Manual of steel construction.

Behaviour and Design of Steel Structures to BS 5950 *CRC Press*

The third edition of this successful textbook is concerned specifically with the design of steel structures to the British Standard BS 5950. Thoroughly revised and updated in accordance with the latest 2000 amendment to Part 1 of the standard, it discusses all aspects of the behaviour of steel structures, and criteria used in their design. With copious worked examples, The Behaviour and Design of Steel Structures to BS 5950 is an ideal course textbook for senior undergraduate students, and will also provide a useful reference source for the practising engineer.