Semi Rigid Connections In Steel Frames The Council On Tall Buildings And Urban Habitat Tall Buildings And The Urban Environment Series

This book is devoted to the discussion and studies of simple and efficient numerical procedures for large deflection and elasto-plastic analysis of steel frames under static and dynamic loading. In chapter 1, the basic fundamental behaviour and philosophy for design of structural steel is discussed, emphasising different modes of buckling and the inter-relationship between different types of analysis. In addition to this, different levels of refinement for non-linear analysis are described. An introduction is also given to the well-known P-&dgr; and P-&Dgr; effects. Chapter 2 presents the basic matrix method of analysis and gives several examples of linear analysis of semi-rigid pointed frames. It is evident from this that one must have a good understanding of first-order linear analysis before handling a second-order non-linear analysis. In chapter 3, the linearized bifurcation and second-order large deflection are compared and the detailed procedure for a second-order analysis based on the Newton-Raphson scheme is described. Chapter 4 introduces

various solution schemes for tracing of post-buckling equilibrium paths and the Minimum Residual Displacement control method with arc-length load step control is employed for the post-buckling analysis of two and three dimensional structures. Chapter 5 addresses the non-linear behaviour and modelling of semi-rigid connections while several numerical functions for description of moment versus rotation curves of typical connection types are introduced. The scope of the work in chapter 6 covers semi-rigid connections and material yielding to the static analysis of steel frames. Chapter 7 studies the cyclic response of steel frames with semi-rigid joints and elastic material characteristics. In the last chapter the combined effects of semi-rigid connections and plastic hinges on steel frames under time-dependent loads are studied using a simple springs-in-series model. For computational effectiveness and efficiency, the concentrated plastic hinge concept is used throughout these studies.

This book publishes the proceedings from the Third International Workshop on Connections in Steel Structures: Behaviour, Strength and Design held in Trento, Italy, 29-31 May 1995. The workshop brought together the world's foremost experts in steel connections research, development, fabrication and design. The scope of the papers reflects state-of-the-art issues in all areas of endeavour, and manages to bring together the needs of researchers

as well as designers and fabricators. Topics of particular importance include connections for composite (steel-concrete) structures, evaluation methods and reliability issues for semi-rigid connections and frames, and the impact of extreme loading events such as those imposed by major earthquakes. The book highlights novel methods and applications in the field and ensures that designers and other members of the construction industry gain access to the new results and procedures.

Definition of semi-rigid steel structural connections, classification and influence to the structural response of sway and non-sway steel frames. Sources of connection compliance, ductility and the application of the component method for characterization of the joint properties. Verification procedures for the available and the required capacity of joints and the design of semi-rigid steel structural connections. Application of the Finite Element Method for the simulation of the structural response of semi-rigid connections taking into account all prominent nonlinear phenomena (cf. e.g. contact, friction and plasticity).

A detailed presentation of the major role played by correctly designed and fabricated joints in the safe and reliable response of steel, composite and timber structures. The typology/morphology of connections is discussed for both conventional pinned and rigid joints and semi-rigid types. All relevant topics are

comprehensively surveyed: definitions, classification, and influence of joint behaviour on overall structural response. Also presented are the application of the component method, the notion of rotational capacity, the local ductility of different types of earthquake-resistant structural joints as determined in cyclic experiments, numerical techniques for the realistic simulation of joint response, simple and moment-resistant structural connections. Readership: An incomparable resource for engineers who analyze and design steel, composite and timber structures; researchers and graduate students in the same areas.

Presenting a comprehensive overview of recent developments in the field of seismic resistant steel structures, this volume reports upon the latest progress in theoretical and experimental research into the area, and groups findings in the following key sections: · performance-based design of structures · structural integrity under exceptional loading · material and member behaviour · connections · global behaviour · moment resisting frames · passive and active control · strengthening and repairing · codification · design and application

At the design stage, column-beam connections of steel structures are assumed as fully rigid or as hinges, and the design is completed with these assumptions. On the other hand, in practice, steel column-beam connections show neither fully rigid nor fully hinge behaviour, and the characteristic behaviour of the connections lies between

these two special cases. Performing realistic calculation of these forces and knowing the behaviour of structures close to reality will decrease life and goods losses to the minimum level in a probable of earthquake to be encountered in the future. In this study, seismic performance of 2-D steel frames were evaluated by Capacity Spectrum Method proposed in the ATC 40 document published in 1996. A new computer program was developed in order to define all geometric and loading data and to perform nonlinear analysis of rigid and semi rigid steel frames for which the performances will be evaluated. In case studies, 3-Floor Steel Frames that have different bay numbers were investigated in various forms according to the rigid and different semi rigid connection types. In addition, the performances these frames for various seismic regions and soil conditions were compared. According to the results, it was observed that semi rigidly connected frames are under the effect of smaller ground acceleration have greater displacement values. As a consequence of this ductile and energy dissipative response, it was seen that the stresses in the members of frame become considerably small, relative to the stresses in the rigid frames'. Furthermore, the performances of semi-rigid frames can be affected negatively beyond such a low rigidity. Consequently, the most convenient design should be made according to the seismic and soil region where the structure to be constructed by performing the necessary studies on the connection details in order to achieve desired performance, serviceability and optimum member criteria.

Semi-Rigid Joints in Structural SteelworkSpringer

Ligações semi-rígidas em estruturas de aço tem apresentado uso crescente na construção metálica, pois é uma opção que permite um melhor aproveitamento da capacidade da estrutura. Neste trabalho apresentam-se as características e a classificação das ligações semi-rígidas bem como a evolução da modelagem numérica e analítica do comportamento destas ligações. Apresenta-se uma metodologia com base no método dos elementos finitos para avaliar numericamente a relação momento-rotação de conexões viga-coluna em estruturas de aço. Parte essencial desta metodologia é a modelagem da ligação e de seus diversos componentes. Um modelo completo em termos da geometria, capaz de representar a interação entre os diversos componentes da conexão é proposto. Esta modelagem inclui a discretização de todos os componentes da conexão: placa e ou cantoneiras, porcas, coluna e viga, sendo a extensão da viga e da coluna a ser considerada no modelo escolhida por calibração do mesmo. O contato entre os componentes da ligação é considerado por meio de algoritmo específico de contato com base na formulação de um problema linear complementar. Considera-se contato sem atrito entre corpos deformáveis. A fim de representar com mais fidelidade as características tridimensionais do problema, adota-se uma modelagem também tridimensional com base em elementos finitos híbridos hexaédricos de oito nós, permitindo o emprego de uma discretização relativamente grosseira. Fenômenos como a presença de grandes deformações, plastificação dos componentes

e a pré-tensão dos parafusos são incluídos no modelo. Os modelos apresentados são empregados para o estudo do comportamento de ligações tipo placa de extremidade estendida e tipo cantoneira de alma simples. Para validação dos modelos são comparados os resultados numéricos com dados experimentais. Analisa-se também a participação da flexibilidade dos diversos componentes da conexão, tais como: parafuso, placa de extremidade, mesa da coluna, na resposta da conexão.

A practical and accessible introduction to the implementation of partially restrained connections in engineering practice.

Abstract: "Beam-to column connections play a very important role in affecting the behavior of structural steel frames. Due to the complexity of semi-rigid connections, analyses based on simple theory are approximate at best; therefore, knowledge of connection behavior is highly dependent on testing. A testing program which will study the behavior of four common connection types is proposed. The program will include the study of shear tab, top-and-seat angle, extended end plate, and T-stub connection types. These four types of connections cover the entire spectrum of connection stiffnesses, from a near pinned condition (shear tab) to a neat fixed condition (T-stub). Important considerations and previously obtained knowledge are presented."

The concept of semi-rigid connection and steel-concrete composite action has been extensively researched in the past. However, they are not widely used in practice due to the lack of detailed information, not only about the

advantages of the semi-rigid design philosophy, but also about the potential risks if its effect is not accounted for. The above considerations were the motivations in taking up this research. Firstly, a numerical study to investigate the effect of connection stiffness on the natural frequency of semi-rigid frame was carried out using ABAQUS software. The results of this numerical study confirmed the necessity of incorporating this effect to get safe and economical design. Consequently, an analytical procedure for a beam with semi-rigid connections under gravity load was developed which overcomes the limitations of previously published procedures. The frequency of a steel beam was also calculated using effective length concept. Furthermore, two new analytical "hand" calculation methods to estimate the first three frequencies of a semi-rigid frame were developed. Both methods were developed by modifying or improving for existing methods in the literature for rigid-jointed plane steel frame to incorporate the effect of connection stiffness. Fist method is suitable only for a semi-rigid plane steel frame which has uniform properties along its height so as it can be modelled as equivalent flexural-shear cantilever beam. The proposed second method is suitable for non-uniform plane steel frame. Both the above methods can be extended to composite structure using the equivalent stiffness concept of composite beam. Moreover, examples of steel frame were used to demonstrate the application of the proposed analytical methods. It was shown that the proposed methods not only can predict the difference in frequency of rigid and semi-rigid frames, but they are also simple enough to be

used in day-to-day design practices. Secondly, as the stiffness of connection is essential in the calculation of natural frequency of a semi-rigid frame, a new simple mechanical component-based model was developed to determine the initial rotational stiffness of commonly used flush end-plate steel or composite connection incorporating the partial interaction effect. The traditional axial spring of shear connectors was replaced by rotational spring to make the model suitable to extending further than the linear region. A chart was developed to estimate the appropriate values of the secant stiffness and strength of a shear stud, since the empirical equations that researchers have used in the past can lead to unrealistic results in some cases. Thirdly, a simplified model, which combined three components of a composite connection in one "lump" component (RCCS), was developed. It can be used in the finite element modelling of a composite connection to overcome the convergence problems associated with cracking of concrete and also it will reduce the computational time significantly with adequate accuracy. A new procedure to determine the number of "active" studs was developed. The relationship between the number of "active" shear studs and the maximum number of shear studs required for a full shear connection was derived. Finally, the relationship between connection ductility and frame ductility was investigated. It was found that the moment resistance and ductility of connection affect significantly the whole behaviour of a frame. Consequently, a simple flowchart to predict the failure mode of a flush end-plate composite connection was developed. A procedure to

estimate the moment resistance of a flush end-plate composite connection by modifying the existing procedures in the literature to incorporate the partial shear connection effect was proposed. Also, the proposed mechanical model was further extended using the appropriate post-linear values of its components in order to calculate the rotational ductility of a connection. All the suggested procedures have been validated with the numerical results using ABAQUS, the results from other existing models and experimental tests in the literature where available.

As ligações estruturais desempenham um papel fundamental no comportamento global das estruturas de aço. Muitos ensaios experimentais desta ligações têm sido desenvolvidos para que se possa avaliar corretamente a influência dos parâmetros físicos e geométricos que influenciam no comportamento destas ligações. Hoje em dia, as ligações no eixo de menor inércia da coluna de pórticos contraventados são dimensionadas como flexíveis. Maiores problemas ocorrem quando este contraventamento não é possível e as ligações rígidas são utilizadas. Todavia, garantir que esta ligação tenha um comportamento rígido, principalmente no eixo de menor inércia, é algo um tanto quanto discutível. Sendo assim, a utilização de ligações semi-rígidas tornou-se viável porque tem um comportamento estrutural que melhor se aproxima da realidade e ainda possibilita uma diminuição do preço final da estrutura. Este trabalho apresenta uma avaliação do comportamento estrutural de ligações viga-coluna em estruturas de aço no eixo de menor inércia.

Uma investigação dos modelos existentes de ligações semi-rígidas na literatura foi realizada e identificou dois modelos estruturais fundamentais para esta investigação: o de Kishi e Chen para o eixo de maior inércia e o de Teixeira Gomes para a menor inércia. Os sistemas de classificação de ligações existentes foram avaliadas mas ainda não se tem conhecimento de um sistema específico para o eixo de menor inércia ou da validade do uso dos sistemas de classificação gerados para maior inércia quando aplicados na menor inércia. Uma análise experimental onde três ensaios de ligação de aço viga x coluna, em escala real foi executada. Esta análise possibilitou a determinação da curva momento x rotação, resistência a flexão da ligação, evolução das tensões e deformações e possíveis modos de ruína. O presente trabalho também propõe um modelo preliminar de ligação semi-rígida com dupla cantoneira de alma e cantoneira de apoio, ou enrijecedor, no eixo de menor inércia visando sua utilização em edificações de estruturas de aço. Uma validação deste modelo preliminar foi realizada através de uma comparação com os resultados experimentais gerados.

As ligações viga-pilar desempenham uma função fundamental para a determinação do comportamento real de estruturas de aço. Portanto torna-se necessária uma avaliação muito criteriosa das reais características geométricas e mecânicas destas ligações, substituindo as tradicionais considerações idealizadas, rígida e flexível, pelamodelagem semi-rígida. Atualmente um dos métodos mais utilizados para caracterização de ligaçõessemi-rígidas se fundamenta no método das componentes, descrito pelo Eurocode 3, que consiste na determinação da resistência e

rigidez dos elementos de maior influência nocomportamento de uma ligação. Com a intenção de se desenvolver um estudo sobre as ligações semi-rígidas, inicialmente foi implementado computacionalmente um sistema de análise e dimensionamento capaz de avaliar o comportamento estrutural destas ligações a partirda informação das propriedades geométricas de ligações viga-pilar executadas com placa de extremidade, produzindo uma base de dados para um projeto estrutural mais seguro. Adicionalmente também foi executado um estudo sobre a otimização do dimensionamento de ligações semi-rígidas, através da criação de um sistema para determinação do modelo ótimo, utilizando-se algoritmos genéticos. Neste sistema, através da variação de parâmetros geométricos, determinados de acordo com a necessidade do usuário, obtém-se o modelo ideal de comportamento dentro de umagama de soluções possíveis. Finalizando o presente estudo sobre ligações semi-rígidas, apresenta-se umanova metodologia para consideração de ligações aparafusadas com placa de extremidade de altura variável, (header plate), que tradicionalmente são consideradascomo flexíveis. Estas ligações foram analisadas através do método das componentes, determinando suas limitações de resistência à flexão e ao corte, juntamente com suarigidez rotacional, efetuando-se modificações nas componentes apresentadas no Eurocode 3.

This book summarizes the recent progress in practical analysis for semi-rigid frame design in North America. This encompasses codes, databases, modeling, classification, analysis/design, and design tables and aids. Practical design methods include LRFD procedures, approximate procedures, computer-based procedures and the optimization process. The book can be used as a supplementary steel design textbook for graduate students, as a training book for a short

course in steel design for practicing engineers, and as a reference book for consulting firms designing building structures.

Semi-rigid steel frames are revolutionizing structural design. This book is a practical professional reference, covering analytical methods for the evaluation of connection flexibility and its influence on the stability of the entire framework. The methods range from a simplified member-by-member design approach to a more sophisticated computer-based advanced analysis and design approach.

Although the semirigidity concept was introduced many years ago, steel structures are usually designed by assuming that beam-to-column joints are either pinned or rigid. Theses assumptions allow a great simplification in structural analysis and design-but they neglect the true behavior of joints. The economic and structural benefits of semirigid joints are well known and much has been written about their use in braced frames. However, they are seldom used by designers, because most semirigid connections have highly nonlinear behavior, so that the analysis and design of frames using them is difficult. In fact, the design problem becomes more difficult as soon as the true rotational behavior of beam-to-column joints is accounted for-the design problem requires many attempts to achieve a safe and economical solution. Structural Steel Semirigid Connections provides a comprehensive source of information on the design of semirigid frames, up to the complete detailing of beam-to-column connections, and focuses on the prediction of the moment-rotation curve of connections. This is the first work that contains procedures for predicting the connection plastic rotation supply-necessary for performing the local ductility control in nonlinear static and dynamic analyses. Extensive numerical examples clarify the practical application of the theoretical background. This exhaustive reference and the

awareness it provides of the influence of joint rotational behavior on the elastic and inelastic responses of structures will greatly benefit researchers, professionals, and specification writing bodies devoted to structural steel.

A practical retrofitting method for enhancing the inelastic performance of existing semi-rigid steel connections is introduced and verified in this study. The method entails adding high-strength steel strands parallel to the beam, passing them through the column, and anchoring and post-tensioning them properly. To verify the proposed retrofitting system, firstly, a series of semi-rigid bolted connections was experimentally tested under monotonic and cyclic loadings. Then, the post-tensioning system was applied on the connections with the same geometry, and the cyclic responses were studied under different post-tensioning parameters. Following the recommended setup explained in this study, a locally post-tensioned (PT) structural frame will experience enhancement in the lateral loading responses in the formed of a self-centering capability and increases in the stiffness and strength. In the experimental approach, the test subassembly was represented by an exterior beam-to-column connection and was constructed with connection angles with three different thicknesses. The specimens were loaded monotonically and cyclically to investigate the complex interaction between the connection components, particularly the bolts and the angle

column leg interaction. A special effort was made to study the effect of the slip between the angle beam legs and the beam flanges on the nonlinear responses of the beam-to-column connections. According to the observed deformation patterns, analytical equations predicting the moment-rotation behavior of bolted angle connections were presented and compared to the monolithically loaded test results. Generally, steel frames with semi-rigid connections experience high residual connection rotations and story drifts following an earthquake that cause significant repair expenses or require demolishing the whole structure. The research studies on PT steel connections showed a self-centering capability that eliminates or reduces these residual deformations after cyclic loading. The general analytical equations for evaluating the effect of post-tensioning on the moment-rotation response of steel connections are presented and modified according to the locally PT system represented in this study. The proposed retrofitting method of existing semi-rigid connections was experimentally tested by adding PT strands to the subassembly setup. This retrofitting setup is applicable to be added to both interior and exterior connections. To anchor the high-strength steel strands, stiffener plates were welded to the beam at the specific length from the column face. The strands were then passed through the column flanges and the stiffener

plates and were anchored against them. Five PT exterior connections with different PT strand lengths, initial post-tensioning forces, and angle thicknesses were tested. Comparing the test results of the PT specimens to the semi-rigid connections without post-tensioning showed the cyclic response improvement. The post-tensioning approach decreased the residual rotation and increased the stiffness, strength, and hysteretic energy dissipation capacity of the connections. Shorter strands provided higher increases in the stiffness and strength; however, the effect of the strand length on the energy dissipation capacity should further be studied. The tension force loss in the PT strands highly reduced the self-centering capability and was more significant in the shorter strands. In the last chapter of this dissertation, the presented analytical equation for predicting the effect of PT strands on the bending stiffness of a PT connection was verified and later modified using the experimental test results.

"This thesis is concerned with the effect of connections of the semi-rigid type on the Plastic methods of structural steel design. The basic principles of Plastic Design are presented, illustrating the formation of plastic "hinges", and their rotational properties. The beam line method for semi- rigid connections, originated by C. Batho, is shown, and a theory presented using this beam line to find the required semi- rigid connection which will transfer

the hinge rotation from the beam to the connection. Experiments are described in which this theory was verified. Two connections were tested to obtain their moment-rotation characteristics. Then two statically indeterminate structures using the same types of connections were tested to demonstrate that all plastic hinges formed at the same load. Finally, the advantages of this method are discussed." --

The purpose of this study is to develop an approach that considers fire as a load in the design of structures. Recent studies of the full-scale fire tests in Cardington, UK and the World Trade Centre collapse have shown that the behaviour of steel structures in fire when assembled into a frame differs from that measured or predicted by fire testing of individual structural elements, revealing the importance of accounting for realistic fire loads in the design of structures and the potential inadequacy of fire testing individual elements as employed by current building codes. Yet, there has been limited basic research and development to allow consideration of fire as a load in the analysis and design of structures. In response to this much needed work, this thesis develops an approach to include fire as a load in the analysis of a 2-bay by 2-storey structure when a semi-rigid connection is exposed to thermal loads typical of those that might be encountered during a real fire. The structural fire analysis is principally based on incorporating

moment-rotation-temperature data for the connection, as found in archival literature, into a structural analysis software package developed at the University of Waterloo. The software employs a modified Displacement Method for analyzing structures, which involves the computation of stiffness reduction factors that represent the deterioration of strength of the structural elements as they are subjected to various loads. By modifying the moment-rotation-temperature data for a semi-rigid connection into a form recognized by the software, a fire load is simulated by incrementally elevating the temperature of the affected steel connection. In this way, a fragility analysis of the entire structure under fire load is conducted. A series of example calculations are presented for cases in which the semi-rigid connection is exposed to increasing temperatures of 20°C, 200°C, 400°C and 600°C. The analysis showed that as the connection is heated, it is weakened, and the steel structure undergoes a redistribution of moments from the heated connection to other non-heated elements within the framework, which is essentially a form of fire-resistance of the assembled structure that unassembled members in isolation do not have. The study also demonstrated that the experimental moment-rotation-temperature data reported in archival literature can be incorporated into the structural analysis, and that additional force-

deformation data obtained from further experimental work or through finite-element analyses would allow the study to be extended to analyze the effects of fire loading on other structural elements of an assembled framework. To demonstrate the link between the predicted structural response at different temperatures and the development of a compartment fire, a fire modelling analysis is also performed.