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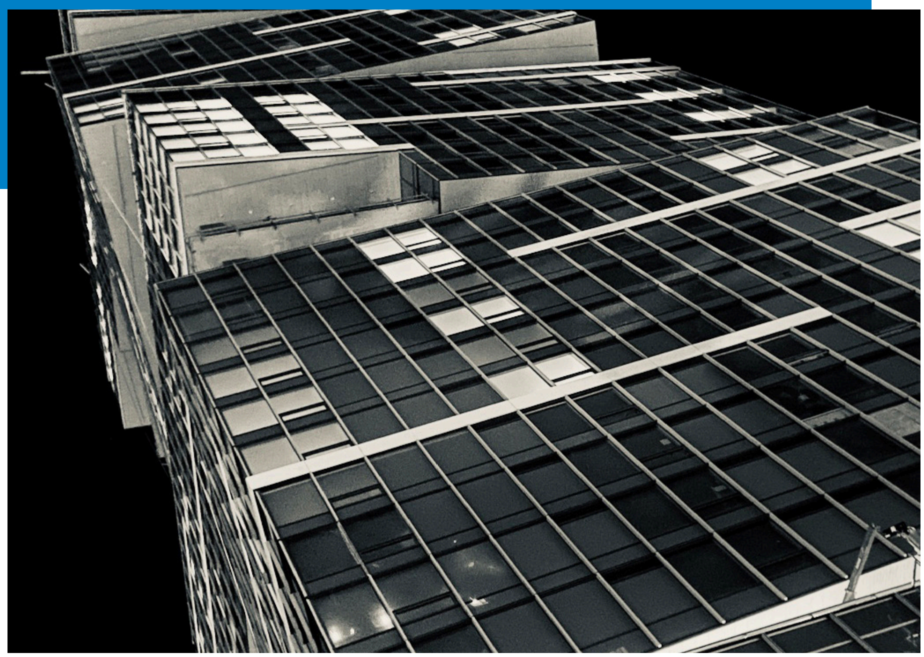

Performance-Based Seismic Design of Concrete Buildings: State of the Practice

Editors:
Jeff Dragovich, Mary Beth Hueste, Brian Kehoe, Insung Kim

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Performance-Based Seismic Design of Concrete Buildings: State of the Practice

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PREFACE

Performance-Based Seismic Design of Concrete Buildings: State of the Practice

Performance-Based Seismic Design (PBSD) of reinforced concrete buildings has rapidly become a widely used alternative to the prescriptive requirements of building code requirements for seismic design. The use of PBSD for new construction is expanding, as evidenced by the design guidelines that are available and the stock of building projects completed using this approach. In support of this, the mission of ACI Committee 374, Performance-Based Seismic Design of Concrete Buildings, is to "Develop and report information on performance-based seismic analysis and design of concrete buildings."

During the ACI Concrete Convention, October 15-19, 2017, in Anaheim, CA, Committee 374 sponsored three technical sessions titled "Performance-Based Seismic Design of Concrete Buildings: State of the Practice." The sessions presented the state of practice for the PBSD of reinforced concrete buildings. These presentations brought together the implementation of PBSD through state-of-the-art project examples, analysis observations, design guidelines, and research that supports PBSD.

This special publication reflects the presentations in Anaheim. Consistent with the presentation order at the special sessions in Anaheim, the papers in this special publication are ordered in four broad categories: state-of-the-art project examples (papers 1-5), lateral system demands (papers 6-8), design guidelines (papers 9-10), and research and observed behavior (papers 11-13).

On behalf of Committee 374, we wish to thank each of the authors for sharing their experience and expertise with the session attendees and for their contributions to this special publication.

Editors

Jeff Dragovich
Mary Beth Hueste
Brian Kehoe
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Performance-Based Seismic Design of the Tocumen Airport Terminal 2

Xiaonian Duan, Andrea Soligon, Jeng Neo, and Anindya Dutta

Synopsis: The new Terminal 2 at the Tocumen International Airport in Panama, currently essentially completed, will increase the airport's capacity to 25 million passengers per year. It has a doubly curved steel roof supported on reinforced concrete columns. The gravity force-resisting systems in the superstructure include long span precast and prestressed double tee decks, topped with cast-in-place concrete diaphragms and supported on a combination of unbonded post-tensioned girders and special reinforced concrete moment frame beams. The seismic force-resisting system includes special reinforced concrete moment frames and perimeter columns, special reinforced concrete shear walls and diaphragms, all detailed in accordance with ACI 318. Located in a region of moderately high seismic hazard, the building is classified as an essential facility and requires a non-conventional seismic design approach to maintain operational continuity and to protect life. Adopting the performance-based seismic design methodology and the capacity design principle, the structural engineering team designed an innovative reinforcement detail for developing ductile hinges at the top of the reinforced concrete columns to protect the structural steel roof which is designed to remain essentially elastic under MCE shaking. The structural engineering team's design has been reviewed by internationally recognised experts and three independent peer review teams.

Keywords: nonlinear pushover analysis, nonlinear response history analysis, performance assessment, performance-based seismic design, Tocumen Terminal 2

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INTRODUCTION

Located 24 km (15 miles) east of Panama City, the capital city of the Republic of Panama, Tocumen International Airport is one of the busiest airports in Central America. The new Terminal 2 (T2), currently with construction essentially completed as shown in Fig. 1and partially operating, will add 20 gates to those of the existing terminal to achieve an estimated total capacity of 25 million passengers per year and will establish the airport as a new hub for the Americas.

Following an international competition and based on the design concept proposed by the winning architectural design firm, a global construction firm was awarded the design-build contract in 2012 to deliver the new terminal. The design firm was subsequently retained to provide full structural engineering services, to be delivered in an integrated manner with those of the in-house architectural and MEP teams.

The new terminal, with a gross area of 116,000 m^2 (1,247,000 ft^2), has a curvilinear shape 660 m (2,174 ft) long by up to 162 m (531 ft) wide on plan and is up to 26 m (85 ft) tall. Arrivals and baggage handling are located on the first (grade) level, departures on the second. A third and fourth level, in the central part of the terminal, provide accommodation for central plant rooms, food courts, airline lounges and offices.
The terminal is divided into five zones along its length, each with its own independent structure from foundations to the roof, via four seismic joints in order to mitigate effects arising from thermal expansion and seismic relative displacements, as shown in Fig. 2.

Among the numerous challenges which are inherent in large scale projects of similar complex occupancies, the major challenges for this project were firstly the fast-track schedule and secondly the complex geometry that led to non-conventional lateral force-resisting systems not listed in Table 12.2-1 of ASCE 7–10[1] and connections not prequalified in accordance with AISC 358–10[2]. The first major challenge was overcome through close collaboration between the integrated multidisciplinary architectural, structural and MEP engineering design team, co-located in the same design office, and the contractor. Structural engineers from the design team were also present on site throughout the two parallel and overlapping processes of design and construction to co-ordinate and assist the contractor with construction administration. This close collaboration enabled construction of the foundations to start only 5 months after project kick-off. The second major challenge was overcome through the adoption of the performance-based seismic design methodology by the structural engineering team.

This paper focuses on the performance-based seismic design and analysis of the Terminal 2 building. The need for a performance-based seismic design methodology as an alternative route to the conventional code-prescriptive approach