Innovation in the Sustainable Design Process of Earthquake Resistant Buildings: From Topology Optimization to Staged Construction Analysis

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Summary

Prescriptive design in seismic regions requires the adherence to stringent criteria and detailing requirements in order to achieve sufficient ductility, redundancy and life-safety performance. In this environment, structural engineers have to rely on innovative solutions to satisfy the increasing expectations on sustainability and aesthetics while maintaining the target budget and schedule.

In this paper, innovative concepts are applied to the design of a courthouse facility. Consisting of a reinforced concrete shear wall system, the building has perimeter columns suspended from a 5 meter deep roof truss. The site presented severe seismic demands, and buckling restrained braces were utilized at the top story to control seismic drifts. Optimization algorithms and staged construction analysis were applied to achieve the most efficient and practical gravity design of the truss.

Keywords: Seismic Design, Roof Truss, Buckling Restrained Brace, Optimization, Topology, Maxwell's Theorem, Staged Construction, Jacking Systems.

1. Introduction

Structural design in highly seismic regions is typically synonymous of complex seismic detailing, prequalified systems, and connections that have to be previously approved by the scientific and professional community. This is done either through actual component testing or rigorous analytical verifications. Architectural and structural solutions are then often constrained by life safety considerations, and only an integrated effort can bring innovative solutions into the projects that can improve structural performance and efficiency. In this paper, innovative design features developed for a major courthouse facility to be located in a seismically active region are presented.

Under the exposure to stringent blast design considerations, the 12 story, 65 meter tall building was developed with a "floating cube" as the architectural concept. The perimeter is supported by hanger columns which transfer the gravity loads to a 5 meter deep roof truss, avoiding any critical vertical element at the perimeter of the first story which would make the building more fragile to progressive collapse in the event of a column removal. The roof truss is supported by reinforced concrete core walls, which therefore become the main gravity and lateral force resisting system of the building. High axial stresses in the wall piers as a result, in combination with heavy seismic weights due to mechanical equipment located at the penthouse level, impose high seismic story shear and overturning demands in combination with reduced ductility capacities. The wall piers and their diagonally reinforced link beams were designed to comply with the seismic detailing requirements of ACI 318 Chapter 21, providing a Life Safety seismic performance for the expected demands of the Design Earthquake (475 years), determined based on tri-directional Response Spectrum Analysis per the American Standards ASCE 4 and ASCE 7.

As far as the load path is concerned, the roof truss becomes the most critical element, given that not only it is essential for the vertical load carrying capacity of the system, but also acts as a collector

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