

## **STRUCTURAL ANALYSIS AND DESIGN OF THE WALT DISNEY CONCERT HALL, LOS ANGELES**

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### **Abstract**

The Walt Disney Concert Hall which is nearing completion of its design and plan check, is a state of the art concert facility. The very unusual shape and architectural characteristics of this structure, imposed an unprecedented amount of engineering effort. Successful structural analysis and design of the project also required composition and merging of various technologies rarely used in structural design of building structures. The objective of this paper is to present an overview of this unique structure and various complex engineering issues that had to be surmounted to achieve a design that satisfied architectural requirements on the basis of sound engineering principles and techniques.

### **Project Description**

The Walt Disney Concert Hall project is being designed as world class concert hall with a seating capacity of 2,380 seats. The project will be constructed on top of the existing Los Angeles County parking structure at the southwest corner of the First Street and the Grand Avenue, immediately south of the Dorothy Chandler Pavilion.

The project has a total floor area of approximately 270,000 sq. ft. above grade and consists of eight elements as follows:

1. The Concert Hall including the "wrappers" and East and West Stair Towers;
2. West Atrium
3. Pre-concert Area;
4. East Lobby and Foyers;
5. East Atrium;
6. Conductor's Suite;
7. Building Base and Los Angeles Philharmonic Office Building; and
8. The Founders' Room.

The exterior enclosure of elements 1 to 6 is a unified composition of metal clad sail-like planes connected by panels of aluminum and glass curtain wall and skylights (Figure 1).

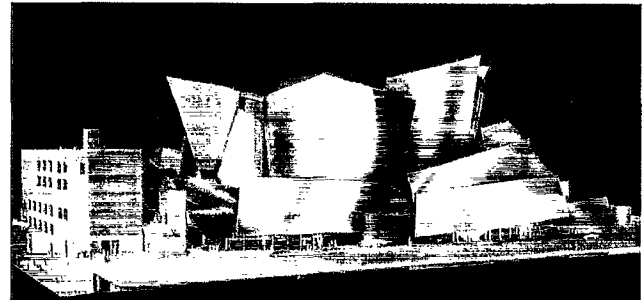


Figure 1. A small-scale model of the project.

### **Importance of Three Dimensional Design and CADD**

This may be the first A/E/C project in the United States where all construction drawings and dimensional controls are defined in terms of fully three dimensional computer models.

The architectural, structural, mechanical, and construction models consisting of very complex curves and surfaces are generated using the CATIA CAD/AM software on a network of Unix workstations. CATIA is a large computer aided design/manufacturing system that is used by Boeing for total design of their airplanes and by Daimler/Chrysler for design and manufacturing of their automobiles.

The wire frames for various portions of the building were developed by close cooperation between the project architects and structural engineers (see Figures 2 to 5).

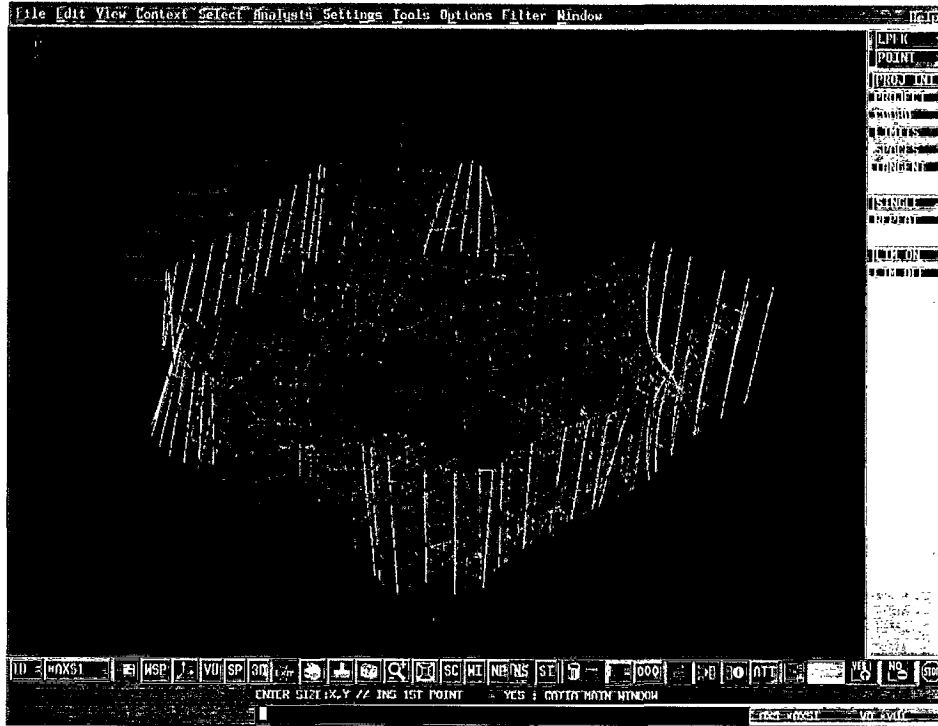


Figure 2. Element 1, The Wire Frame for Concert Hall and Stair Towers

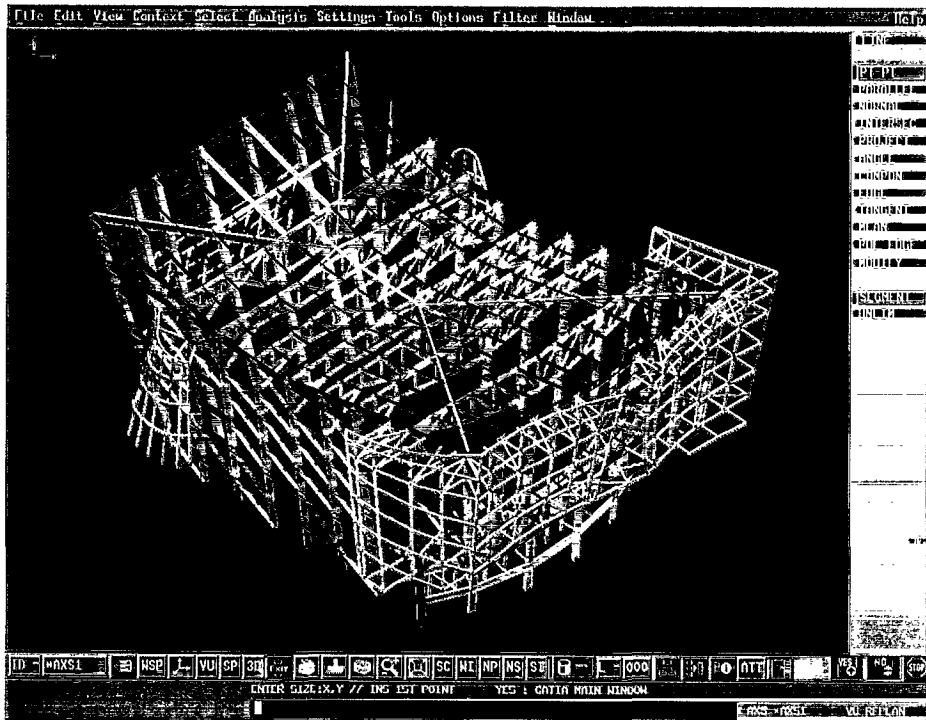


Figure 3. Element 1, The Structural Model for the Concert Hall and Stair Towers

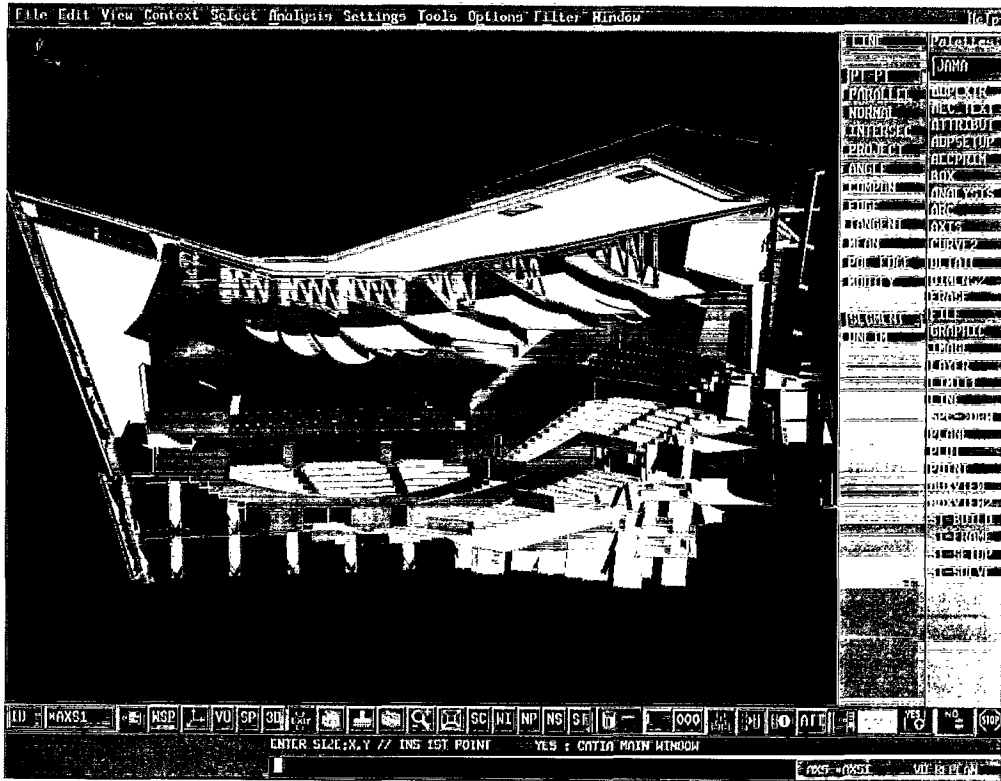


Figure 4. Element 1, A section through the Structure and Architecture of the Concert Hall and Stair Towers



Figure 5. Element 1, CATIA Model of the Completed Exterior

The structural model extruded in CATIA is then converted by a series of in-house developed translators to a SAP2000 computer model for the purposes of structural analysis and design (see Figures 6 and 7). The design results are fed-back to the CATIA model (Figure 8).

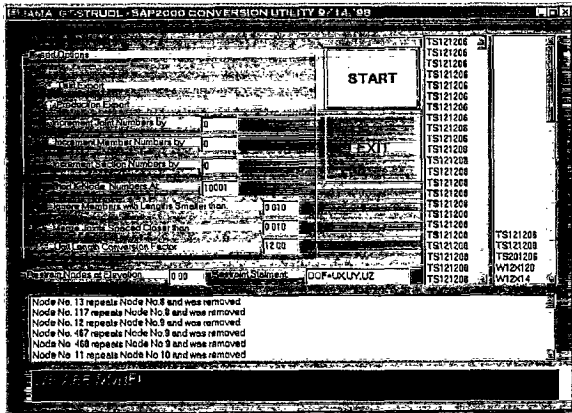


Figure 6. The in-house developed CATIA/SAP2000 Translation Interface

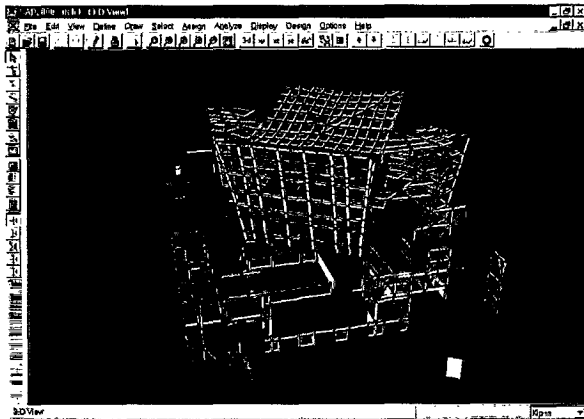


Figure 7. A view of a partially converted SAP2000 model of the Concert Hall.

The structural system for the Concert Hall is a complex set of interconnected steel braced frames and trusses. Originally, a structural steel moment frame system was envisioned for the project. However, in light of the experience with steel moment frames during the 1994 Northridge earthquake, a braced frame alternative was substituted. The difficulty in utilizing steel moment frame system for this structure is particularly due to the fact that most “beams and “columns” of the structure intersect at non-orthogonal angles. Furthermore, on many cases several

structural straight and curved members intersect at odd angles at a single point in space.

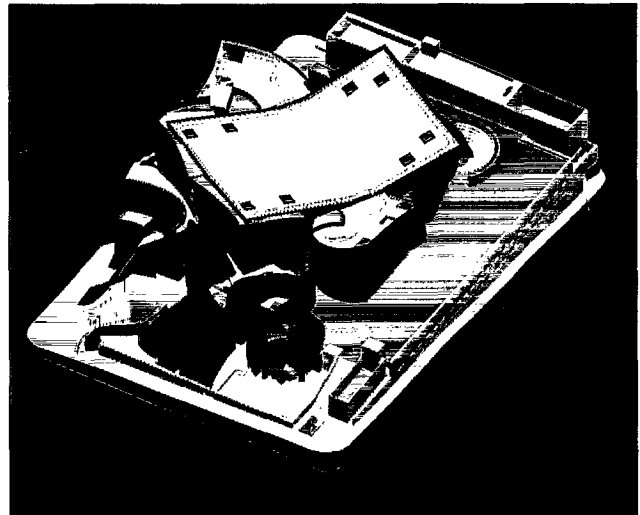


Figure 8. The completed CATIA model of the building

The parking garage on the top of which the Concert Hall will be constructed is subjected to a series of comprehensive analyses to ensure its adequacy and to modify it where necessary. The complexities of the tasks at hand may be illustrated by the fact that the finite element model of the garage roof slab alone requires the solution of 380,000 simultaneous equations with as many unknowns (Figure 9).

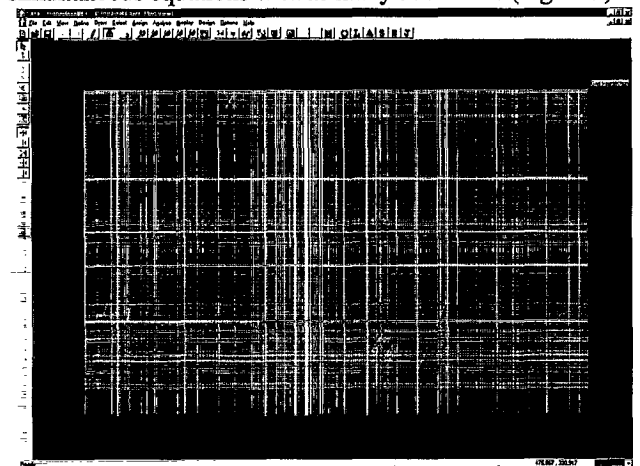


Figure 9. The Finite Element mesh generated for the SAFE model of the parking structure slab.

This presentation will provide an overview of this project and the seismic analysis and design challenges being faced by the design teams.