TUNING THE STRUCTURAL ENGINEERING MIND IN CREATIVE WAYS

PETER LAURSEN
California Polytechnic State University, USA

Architectural Engineering (ARCE) at Cal Poly is uniquely located in the College of Architecture and Environmental Design. The ARCE program has a strong emphasis on structural engineering and is infused with exposure to architecture (ARCH). For example, first year ARCE and ARCH students participate alongside each other in a full year architecture design studio sequence. Towards graduation the engineering and architecture students engage in an interdisciplinary capstone experience.

The first part of the presentation will discuss the interdisciplinary nature of the ARCE program and present examples of, and lessons learned, on collaborative efforts between engineering and architecture students. It was found that interdisciplinary collaboration through the conception and execution of projects fosters creativity, engagement and ownership, leading to a better understanding of each other's fields. The second part of the presentation will focus on recent international projects involving creative concrete solutions. Projects will include engineering solutions in new design and retrofit, with natural emphasis on seismic loading, and include projects where interesting architecture is interconnected with structural engineering.

CONCRETE SHELL STUDIO

At Cal Poly, Architectural Engineering and Architecture students join forces in the interdisciplinary studio to design, analyze and construct thin concrete shell structures. The capstone experience is team taught by architectural engineering and architecture faculty. Professor Saliklis explains, "Normally architects design the structure, and engineers calculate the beams and columns, a scenario that doesn't require collaboration." Professor Killing further explains, "The course flips that concept, with architects and engineers working together from
the first week, simply because the architectural and structural forms are so closely intertwined." The disciplines of architecture and structural engineers are blended to create 2.7 m (9 ft) long physical models as well as virtual designs of the shell structures. To create the compression-only concrete shells, students start with tutorials on geometric form-finding tools and then go into a model-based approach, to ensure compression only structures. Students built physical models using chains and weights to examine pure catenary action. Then they build cloth models wetted with plaster. As the plaster models are flipped upside-down, they represent a pure compression structure with no bending. Faculty from both departments agree that designing thin concrete shells collaboratively reclaims trends from the '50s and '60s. "An architect can't do it alone, and an engineer can't do it alone." Students agree and an ARCE senior explained, "This class is our first opportunity to work with architecture students who have gone through four years of education. It's really inspiring and helps pave the way for my future working in industry with architects." An architecture student stated, "It is the only opportunity we have had to work alongside engineers and see how structures are integrated into architecture. The course gives us an opportunity to bounce back and forth the ways we can influence each other."

**ORANGE COAST COLLEGE PLANETARIUM**

The Orange Coast College Planetarium is currently under construction. The structure houses a Planetarium Dome, a Foucault Pendulum exhibit, and various ancillary support spaces. The Planetarium will provide educational opportunities for local elementary school students, college astronomy classes, and planetarium shows for the local community. This part of the presentation will focus on the structural function of the 19 m diameter concrete dome, the surprising construction method, and its interaction with complex structural steel framing radiating from it. For ease of construction, the lower part of dome was built as a cylinder up to an elevation of 2.8 m (9'-3"). It then curves inward toward the top at an elevation of 12.9 m (42'-3"). The spherical part of the dome was constructed using a shotcrete technique. A membrane was inflated to form the desired outer surface geometry. Rebar was placed against the membrane and the concrete shell formed with shotcrete. After completion of concrete construction, the membrane remains in place and serves as weather-proofing. The dome also serves as a main shear wall within the lateral system. Collector beams transfer lateral loads from the concrete roof diaphragm into the dome.
The Academy Museum of Motion Pictures (AMMP) in Los Angeles will be the world’s premier institution devoted to exploring the art and science of movies and moviemaking. Designed by architect Renzo Piano, the museum will consist of a major renovation to the 1930s Streamline Moderne May Company building, plus a soaring spherical addition that will house a 1,000-seat theater. The AMMP is currently under construction. This part of the presentation will focus on the design of the spherical concrete shell theater superstructure. The complex shape of the concrete shell was modeled parametrically such that design alterations from the architectural creative process could be incorporated quickly. Being located in a highly seismic area, design of the lateral system was critical to structural safety. Large overturning forces had to be mitigated by the two concentric support points. A base isolation strategy was selected. The complex shape of the curved concrete walls is achieved with a shotcrete solution, where the external precast cladding panels serve as formwork for the concrete walls.

The Folsom Cordova Unified School District Education Services Center in California, utilized an innovative design solution to construct tilt-up concrete over the 40-foot (12 m) code height limit in high seismic zones. To meet the demands of the architect and the developer, Special Reinforced Concrete Moment Frames (SRCMF) were chosen to function as both the exterior skin as well as the lateral force resisting system. The advantage of using SRCMFs is that there is no code height limit, while precast walls are not permitted over 12 m (40 ft.) of height. In
order to meet the strong-column/weak-beam code criteria for the 16 m (52 foot) tall building, the panel beams were slotted to reduce the structural depth. Panel rebar fabrication was primarily performed in the rebar fabricator's shop and sent as units for final site assembly. Using the tilt-up construction method allowed for substantial cost savings while meeting the required performance criteria.

These are but a few examples of how the structural engineering mind can be tuned in creative ways.

IMAGE CREDIT

[1] Ed Saliklis, Dep. of Architectural Engineering, California Polytechnic State University
[3] Daniel Fox, MHP Structural Engineers