

Building for the Future: Evaluating the Current Viability of Thin Shell Concrete Structures

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EXECUTIVE SUMMARY

The thin shell structures of Felix Candela are among the most sophisticated examples of structural invention produced in the twentieth century. Their elegant forms are the result of a unique convergence of architecture, engineering and construction concerns. At a time when architects are increasingly attracted to complex forms, the rationality and efficiency of Candela's work is an important example for present-day practice. Through an investigation of the work of Candela, we have successfully accomplished three goals that expand the base of knowledge in both architecture and engineering design as applied to thin shell concrete structures: (1) performed detailed structural analyses of Candela's most sophisticated structures; (2) written a book on Candela; and (3) built models of Candela's best works for exhibit in an art museum.

Since Candela built these structures in the 1950's, he did not use computers to analyze any of them; instead, he used membrane theory, which he verified with simple calculations that he developed by reducing what appeared to be a complex form into something as simple as a cantilever or a three-hinged arch. We found that in many cases these simple equations lead to the same solution as complex nonlinear finite element solutions. Candela's structures are all still standing in excellent condition today because the form that he selected for his structure was a form that is proper for resisting the intended loads. This same form, one that employed the hyperbolic paraboloid (hypar) geometric shape, also led to efficiency of materials and construction. Since the form is selected to accommodate the forces, his shells needed only to be 1.5 inches. This thickness was based on practical limitations since the stresses in the shells were well below the strength. In addition, the geometric attributes of the hypar form permitted straight (as opposed to curved) forms, thus achieving economy of construction. This efficiency of materials and economy of construction did not come at the cost of elegance as his completed works have shown.