Experiment:
Proving the Supposed Arbitrary Original

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In 1954, Felix Candela introduced the notion of the Supposed Arbitrary Original. What follows shall be a discussion of this notion and its' relevance to contemporary practice and education.

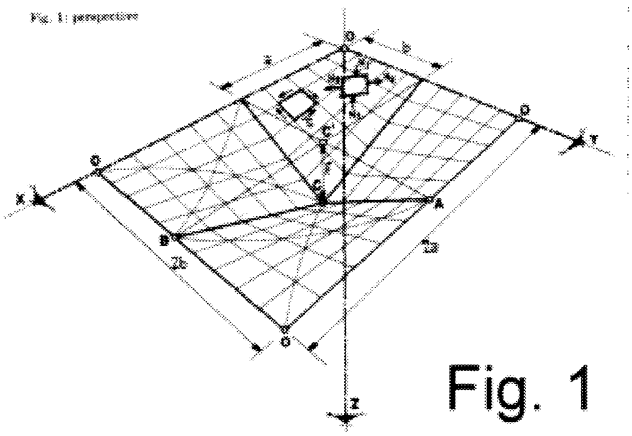


Fig. 1

"It is forgotten that mathematics is only a means,... but that the rigidity and precision of mathematical reasoning can not guarantee us the exactness of the results of its application because we must always begin from a supposed arbitrary original." [1]

—Candela

We possess a standardized kit; we choose from bricks, wood balloon frame and standard steel sections. As a result, the imaginative forms we see on the boards, in reality, often dull by comparison. It is time to question the materials kit the same way we question building forms. By experimenting with the kit, questioning the standards, we can substantiate new construction methodologies and as a result, realize the Supposed Arbitrary Original through the very real experiment of building. A scientist proposes a hypothesis as provisional conjecture to guide an investigation in light of established facts. To prove the hypothesis, the Supposed Arbitrary Original, one experiments. To experiment is the act of testing a supposition in order to discover something not yet known. Will it pass? Will it fail? How does one judge the results? By testing until the point of failure, the scientist can establish the parameters of the supposition. What makes it true and what makes it false? As a premise, building design professions also begin with the Supposed Arbitrary Original: I have an idea; I want to build it. Unfortunately, it seems we have forgotten what it means to experiment.

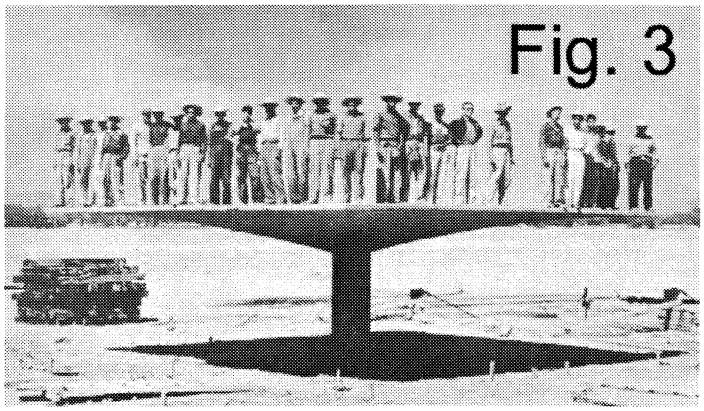
Fig. 2

"I sometimes allow myself to fancy that progress of the structural technique could have taken place by means of the natural evolution of intuitive and experimental methods employed with such amazing success in the Middle Ages and the Renaissance. Perhaps such a development. .....could have led to a better use of the properties of the materials, for the problem might have been approached more openly, without the blind faith that it may be solved by mathematical procedures. The most fitting forms are not, as a general rule, easy to investigate.....; hence their use has been neglected in favor of less appropriate solutions that are easier to analyze." [2]

—Candela

The experimental method provides a structure to explore and investigate the unknown of that which is not understood. It utilizes deductive reasoning to frame, perform, and analyze the experiment. It utilizes inductive reasoning to interpret, conclude, and generalize the results. This combination of accumulated experience (deductive) and personal decision (inductive) to research a hypothesis is applicable to our profession. Architects practice the art and science of designing and erecting buildings: the designing - our hypothesis, the making - our experiment, the building - our proof. Undoubtedly, our profession and education system consistently hypothesize new forms. Instead of making through experimenta-

tion, however, we assume the methods of construction to be predetermined by existing standards and requirements. This assumption belies the hypothesis because the variables it adds to the experiment can corrupt, contradict, and/or subvert the results. If architects are going to substantiate a Supposed Arbitrary Original, they must be willing to experiment towards its proof.



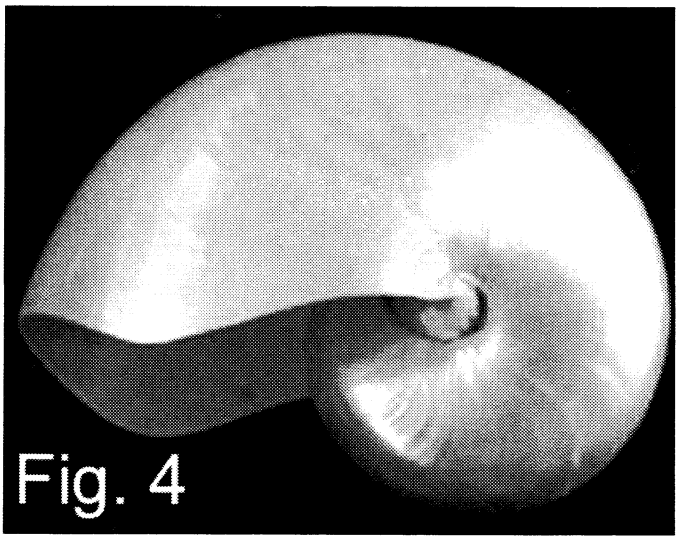
" I am a practical man, because I have no choice. I must be practical in order to survive and therefore I choose only to build structures that I can calculate myself. Of course there are many opinions regarding the question of calculation, and it is a highly personal problem how far one is to calculate. Myself, I believe that if the structure stands up with the simple calculations I make, that is enough."[3]

—Candela

To illustrate how the experimental method is applicable to the profession of architecture one only has to look at Felix Candela. Born in 1910 in Madrid, Spain, he received his architectural education from the Escuela Superior de Architectura de Madrid. While in school he developed a proclivity for geometry and began to tutor his fellow students. This experience coupled with a fascination for the stability of structures gave him the confidence to pursue shell design. Familiarizing himself with the theoretical basis of the current methods of calculation for indeterminate structures, Candela initially felt that mathematics was the key to understanding. In 1936, upon graduation, he received a scholarship to pursue his study. The Spanish civil war came however and he joined the Republican Army. Refusing to join Franco's Spain, in 1939 he was forced to seek safety in Mexico. Upon arrival he was appointed as an architect of a Spanish colony north of Chihuahua, but after a few years the position dissolved. He relocated to Mexico City and worked as a draftsman. As soon as he was able, he brought his family over and with them founded Cubiertas ALA, a roof construction company. It was at this time that his interest in shells resurfaced and he began to experiment.

"Nature's most usual way of performing this function is by means of either rigid shells or elastic membranes. Since this second form can hardly be considered as architectonic, "shell" remains a synonym of space enclosure and the title of this essay (Shell as Space Encloser) appears to be somewhat redundant."[4]

—Candela

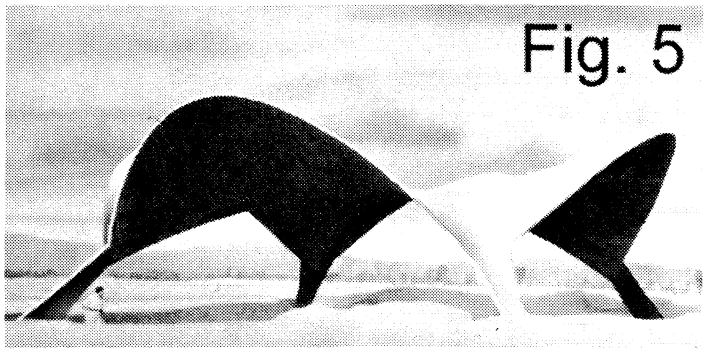


Historically, Candela is described as the multi-faceted practitioner – Architect, Engineer, Builder (Contractor). Candela as the Experimentalist, however, is what defines him. It is his foresight to experiment in the plasticity of form that establishes his contribution to all three of the aforementioned practices. Intrigued with shell design from the onset, he conceived a Supposed Arbitrary Original around the spatial structures of concrete shells. Candela supposed shells could be an economical way to cover space if they were sensibly designed, and concrete was the only practical and economical material that could capture the fluidity of the shell form. In order to prove this to himself, he fervently studied the geometry of the shell and the capabilities of the material, analyzing their relationships in order to bring out the full potential of the structure. He did this acknowledging that since the advent of the Mathematical Theory of Elasticity experimental knowledge no longer validated structural design. It had to be mathematically proved before one could be allowed to occupy it. Finding the mathematics pseudo-scientific and unable to account for the behavior of the material, he almost gave up his research for fear of failure and lack of acceptance. Intuitively inspired, however, by the pictures of Maillart's Zurich Exposition shell, in 1951 he abandoned his caution and began to construct experimental shells. "One must be sure he is building something which can stand."

Following these physical proofs, he received his first public commission, The Cosmic Rays Pavilion for UNAM, the National University of Mexico. In order to allow cosmic rays to penetrate the building, Candela constructed two hyperbolic paraboloidic vaults along a principal parabola that he stiffened with three arches. This form allowed him to pour the thinnest roof that had ever been constructed: 5/8" at the crown increasing to 2" at the springings. The pavilion, though small, had quite a presence and was the first public validation of Candela's Supposed Arbitrary Original. His experiment had paid off and, within the realm of his initial hypothesis, he spent a career developing, enhancing, constructing, and educating.

"The essential function of architecture is to limit a volume from the non-architectural extent of open space, so that within it man may develop his living activities undisturbed by weather inclemency's. The unique feature which distinguishes architecture from other plastic arts is precisely this dealing with internal hollow space."[5]

—Candela



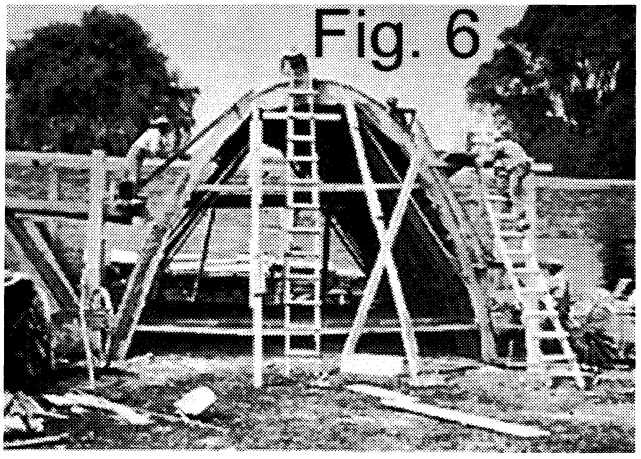
Submitting the winning entry in a competition, Candela's second commission was La Iglesia de la Virgen Milagrosa (1954). This commission, granted because it would be economical to construct, became much more than an efficient structure. Building on the technological knowledge he had acquired from his test shells and the Pavilion, Candela added another variable to his experiment: spirit. Here the hyperbolic paraboloidic shells, clustered like a flock of origami birds, designate the ecclesiastical program. Along the minor axis, they distinguish the nave from the aisles. Along the major axis, their crimped joints ascend towards the altar establishing monumentality. This delineation of spaces combined with the reflection of the stained glass along the ribbed formwork surface and the contorted slender columns that pin this church, almost pure roof, to the ground exhibits Candela's ability to combine structure with poetic expression. As a building, La Virgen Milagrosa can be seen one of the most successful modern spaces to capture the gothic spirit. For Candela, his Supposed Arbitrary Original that shells can provide cover combined with his professional duties to delineate hollow space resulted in an individualistic architectural statement.

"This inquiry has never been more pertinent than now when a monolithic material which can be cast in any desired form has become of common use in building. Reinforced concrete is not only very akin to the stuff of natural shells, but it has even the advantage of being able to withstand substantial stresses. These properties of continuity and tensile strength of reinforced concrete place before us a unique opportunity to emulate the distinctive economy of material of natural methods of enclosing space."[6]

—Candela

As stated in the rules of the experimental method, besides the supposed arbitrary original (for Candela, the shell) and the acquired knowledge (architectural education and research), one must also have the means with which to execute the experiment. For Candela, concrete provided the means of execution. It is a monolithic fluid material able to capture any imagined form and when reinforced it possesses the ability to resist substantial tensile stresses. Candela acknowledged that combined, these qualities emulated the characteristics of natural shells. He also understood that the material was subject to many chance variables and so in order to control them, his experiments had to be full-size. Thus each project was an experiment where, upon completion, he interpreted and generalized the data and then utilized it to inform the next test. One only has to look at one of his later works to see the results of this ever-widening research.

The restaurant, Los Manantiales at Xochilmilco (1958), serves as a prime example. Completed twenty years after his initial test shell, Candela considered it the culmination of his research. A 1 1/2" thin continuous surface undulating in the shape of a lotus flower and spanning 150 feet, Los Manantiales stands free of the cumbersome details that marked his early works. It is edge-free: marred by no rim beams or stiffening ribs. It is all that a shell should be: thin, taut, continuous, graceful, and light.



"Now I am asked to do other things about which I don't know anything. I am being asked to cover very large areas because it is said. 'This man does beautiful small shells': so they ask me to build a 500 ft. shell. Of course I can't do it, I have to begin to think again and this is a terrible problem because thinking is one of the most painful tasks that one can have. It is incredible the amount of work that people do in order to avoid thinking."[7]

—Candela

Seeing Los Manantiales as the proof of his Supposed Arbitrary Original, Candela used the results to complete just a few more concrete shells. For him, the capabilities of the hyperbolic paraboloidic concrete shell had been exhausted. He did not stop experimenting, however, reluctant though he was. In 1964, he collaborated with Enrique Tamborrel and Antonio Peyri to design and construct the Olympic Stadium (1968) for the Mexico City Olympics. Composed of copper plates, steel structure, and concrete struts, this 500' span geodesic dome represented a new phase of experimentation. To adapt to the new circumstances Candela utilized the knowledge acquired from proving his initial hypothesis and enhanced it. For Candela, within the familiarity of anyone's existing realm, new ideas could be supposed and then substanti-

ated. One could argue that the expansion of our realm has outpaced the expansion of our familiarity. In our struggle to grasp the parameters of our new existence, a reliance on certain tangible standards has begun to belie our progressive hypothesis.

"On the other hand, in times of plenty there is a tendency toward mental slothfulness. We have already every conceivable kind of material, and their properties are continually improving. Why should we trouble to look for new forms or worry about design when it is so much easier to demand just a little more resistance of a certain material." [8]

—Candela

It can be said that Candela did not trouble to look for new forms. The forms he began with originated from one genus (nature) and then he placed them in another (architecture). It is only in their assimilation that they evolve into something other: the other, a result of his experiment, his demand for just a little bit more from a material combined with applied imagination and knowledge. Technology advances in the past 20 years have expanded exponentially the origins of the Supposed Arbitrary Original. Revolutionary hypotheses occupy our two-dimensional and three-dimensional virtual worlds. In comparison, Candela's seems childish. Shells make space. At the time, however, it too was considered revolutionary. He had to experiment with making to substantiate his Supposed Arbitrary Original. The experiments served to prove his point. Imagine if the contemporary origins, intents, and forms also experimented with new methods and materials. Together, they would assure the achievement of a determined and desired architectural expression.

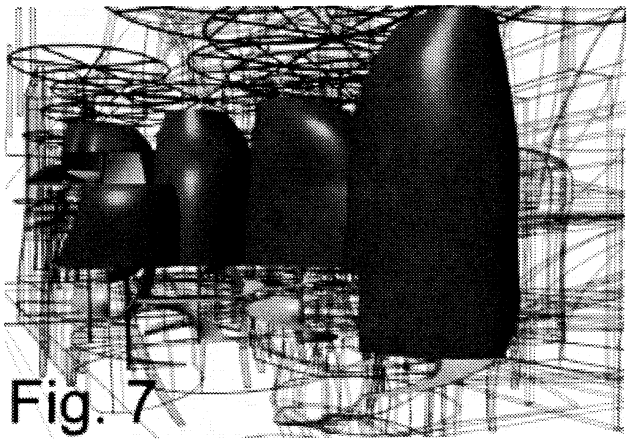


Fig. 7

"Quoting the older aphorism 'Function creates the organ' (which curiously enough links the words that name both outstanding trends of the modern movement) a well known postulate of functionalism states that 'Form follow function'. But architecture is not made with words, and in the practical application of both sentences it is often forgotten that the creation of new forms can only take place by means of structure." [9]

—Candela

In the age of computers, architects Suppose Arbitrary Originals continuously. As hypothesis however, they often seem to be conjectures concerned mostly with testing origins and form and not with testing the physical. This is substantiated by their relegation to virtual reality or if they do in fact get built, the use of the existing construction and materials kits belies the hypothesis. If the proofs of Supposed Arbitrary Originals are the structures we make, the making too must be guided by the supposition. To design and build need not be separate in our profession. For every imagined new environment we must also imagine how it comes to fruition. We must question how we make structures the same way we question origin and intent. Felix Candela was an architect. He had an idea and he wanted to build it. To do so he experimented through making to acquire the knowledge to prove his Supposed Arbitrary Original.

"If a rebel was able to produce such beautiful and sound structures there could be nothing wrong with becoming a rebel myself." [10]

—Candela

HYPOTHESIS

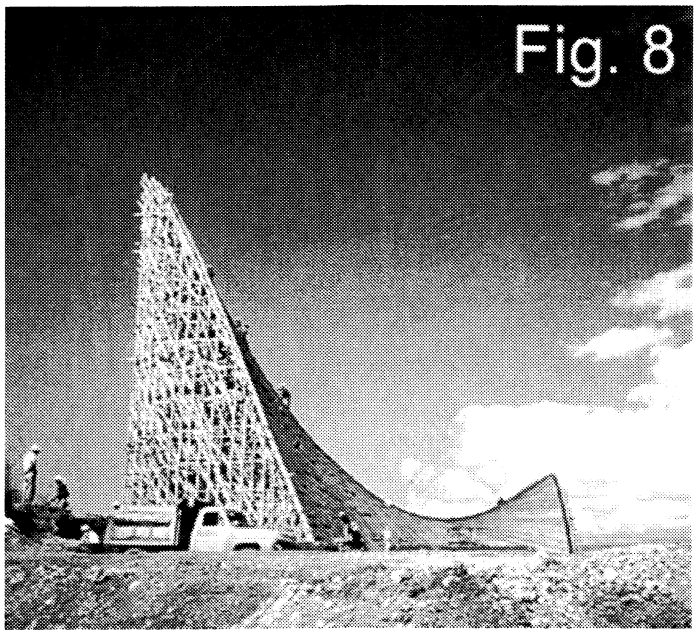
As our access to information becomes hyper-access, the building professions could be on the verge of a construction renaissance. As the creators of boundaries, the protectors from the outside, we are responsible for constructing shelter. In order to transform, reform, and imagine new environments, we must be able to Suppose an Arbitrary Original and be willing to experiment for its *Proof.*

What are the contemporary parameters of proving the Supposed Arbitrary Original?

Does fear of failure (the premise of experimentation) prohibit the questioning of construction materials and methods?

Can we teach future generations to utilize the scientific method of discovery?

How do we gather support for experimentation from our peer professions and industries?



"Man is capable of many kinds of bravery: the least noted of these are the new structures he builds."[11]

—McCoy

NOTES

[1]Felix Candela, "Toward a New Philosophy of Structures," Student Publications of the College of Design, North Carolina State (1954): Vol. 5 # 3, 2-12

[2]Felix Candela, "The Shell as a Space Encloser," Proceeding, Conference on Thin Concrete Shell, MIT (June 1954)

[3]Felix Candela, "Shell Structure Development", The Canadian Architect, (Jan 1967): Vol.12, 33-40

[4]Felix Candela, "The Shell as a Space Encloser," Proceedings, Conference on Thin Concrete Shell, MIT (June 1954)

[5]Ibid

[6]Ibid

[7]Felix Candela, "Shell Structure Development", The Canadian Architect, (Jan 1967): Vol.12, 33-40

[8]Felix Candela, "Toward a New Structure," Architectural Forum, (1956)

[9]Felix Candela, "The Shell as a Space Encloser," Proceedings, Conference on Thin Concrete Shell, MIT (June 1954)

[10]Colin Faber, Candela/ The Shell Builder (Reinhold Publishing Corporation, 1963)

[11]Esther McCoy, "Mexico Revisited (II): The Presence of Candela," Zodiac (1963): Vol.12

ILLUSTRATIONS

Fig. 1 Hyperbolic shell diagram. Colin Faber. Candela/ The Shell Builder (Reinhold Publishing Corporation. 1963)

Fig. 2 Renaissance Alchemists. Author unknown

Fig. 3 Test Umbrella. Colin Faber

Fig 4. Seashell

Fig. 5 Guadalajara Sales Office. Colin Faber

Fig. 6 Test Shell. Colin Faber

Fig. 7 Digital Rendering of a Student Project. Columbia Abstract 95-96

Fig. 8 Formwork for Cuernavaca Chapel. Colin Faber