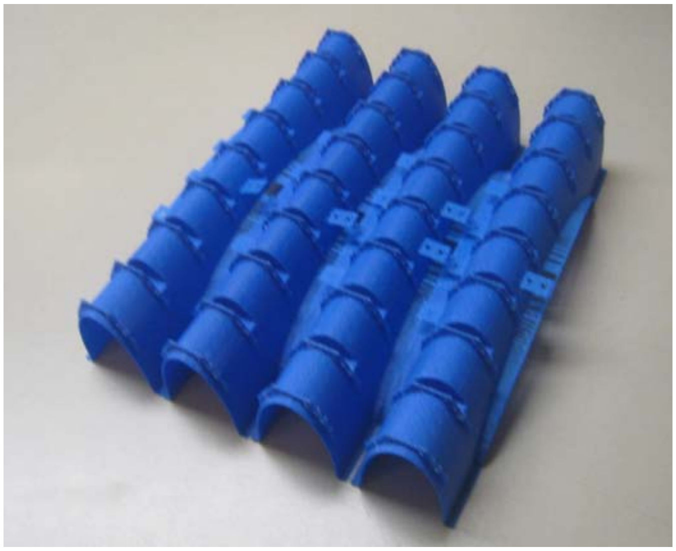

Solar Tectic Concrete Floor and Roof Ceiling System Without Steel Reinforcing

Development Notes

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By Michael Molinelli, AIA NCARB LEED ap

Molinelli Architects
279 SLEEPY HOLLOW ROAD
BRIARCLIFF MANOR, NY 10510

TEL 914 941-2657

www,molinelliarchitects.com

PURPOSE
The purpose of this report is to document the status of the idea behind the patent granted for the Concrete Floor and Ceiling System Without Steel Reinforcing. While the idea has gone through some development and limited testing, it still needs much more effort put behind it to verify if it works and is economical.

BASIC IDEA BEHIND THE PATENTS
For those who have not read the patent, the basic idea is that non-ferrous formwork, of a particular geometry might be able to replace the use of reinforcing steel in the construction of flat elevated concrete surface such as floor or roofs. (If the formwork is exposed in is also the ceiling.) The thermoplastic formwork will come in standard lengths such as 10 feet, 12 feet, 16 feet etc. *(3.0 meters, 3.7 meters, 4.9 meters.)* It is consumable. It is used once and after it is set in place it would remain as part of the construction. The thermoplastic formwork would arrive on site be unpacked and stacked; be set in place, anchored and shored up; have concrete poured over it and worked into the form; and then be allowed to cure.

It is hoped that the ease speed of setting the form work and relatively lost cost of the materials of the forms would become an economic benefit. This would propel this system to be the system of choice for most poured in place concrete work throughout the world.

This report references the following patents:
- US 8,9991,137 B2 published March 31, 2015
- US D773,696 S published December 6, 2016
- US 2017/0268242 A1, published September 21, 2017

WHAT NEEDS TO BE DONE?
The idea has germinated and gone under some modifications as we have moved through different patent processes. There are some very basic questions that could easily be answered with a little research and experimentation. These questions include:

1. <u>Does the idea work?</u> Can such a system bear loads sufficient for practical use such as 30 to 40 pounds per square foot (*146 to 195 kilogram-force per square meter*) for the span. Our scaled down experiment shows it does work.

2. <u>Can these forms be manufactured and shipped economically?</u> The manufacture of thermoplastics is not part of our expertise. We appreciate that the form might need to be modified to make manufacture feasible. Once manufactured, the forms take up space and will require shipment to locations. We don't know how shipping costs affect the economic benefits. We also don't know what the target cost needs to be for this system to become the system of choice.

3. <u>Will the system perform in the field as expected?</u> There are probably many operational and performance issues that need to be resolved before this system will be as easy and economical as we project. And there might be nuances about anchoring and shoring that we need to investigate.

DOES THE IDEA WORK?

It does.

Background
Concrete construction has brought many advantages to the construction industry since being reintroduced to the world in the late 19th century. Poured concrete was used in ancient Rome, famously for the dome of the Pantheon, but the recipe was lost for millennia. Concrete (composed of Portland Cement, sand, aggregate and water) offers many advantages to other types of framing:

- It is composed of basic and easily transported materials
- It is malleable when first mixed so it can assume many shapes
- It has great compressive strength
- It is resistant to fire

But concrete is poor in its tensile strength. For this reason, its paired with steel often in the form of re-bar (reinforcing bars) and/or wire mesh both of which are expensive and labor intensive regarding transport and placement. Concrete also requires a labor-intensive formwork to be placed and, after the concrete is set, removed. While modern reusable form systems have reduced the cost, of material the labor costs remain.

The Innovative Idea
Our idea is to is use a consumable thermoplastic formwork work that can be massed produced. This formwork would be set in place, in an interlocking fashion that would allow the concrete to be poured in place without re-bar or mesh. The formwork's geometry (using parabola's and arches) and its articulated surface (increasing surface friction and allowing the concrete to grab and interact with the form) will push the concrete to almost pure compression. The thermoplastic form would also provide the minimum tensile strength needed. We suspect the forms will still need temporary shoring while the concrete sets.

This would allow for quick and less expensive means to build flat floors and/or roofs that are capable of holding 30 psf *(146 kilogram-force per square meter)* live load or more.



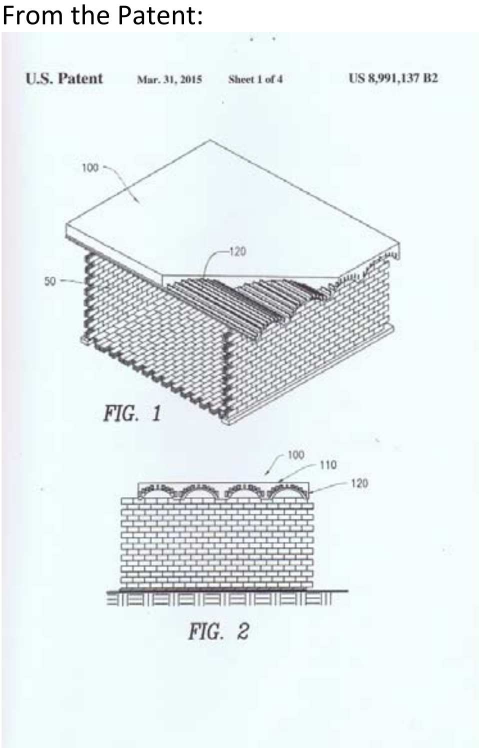
What distinguishes this from all other systems we have seen is the formwork is permanently placed – that is it is consumed each time it is used and the system does not require steel reinforcing of any kind. It works to create a monolithic material distorted in two planes which is how the concrete overcomes the lack of tensile strength.

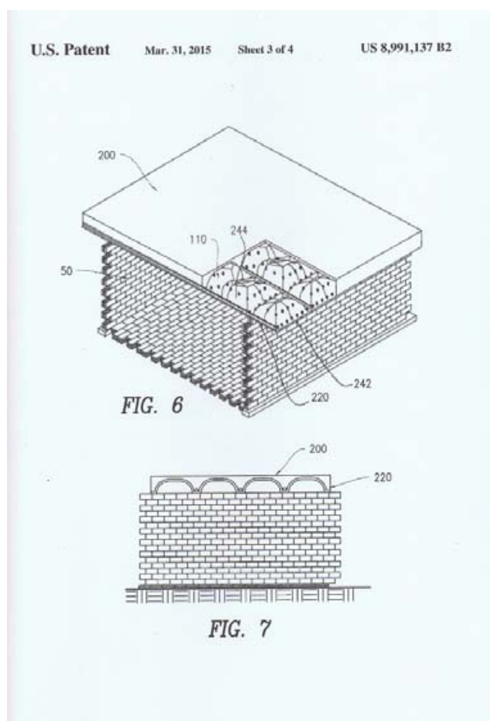
Distortion in two planes is the principal behind the many concrete shells used around the world. Architect Felix Candela has used the principal many times as seen in some of his projects below. This system saves on materials but tends to be labor intensive. It still uses steel mesh to give the concrete shell some tensile strength and requires a very intricate and special formwork. For this reason, it has not caught on in many developed nations. They use it only when pursuing a particular aesthetic and not for any economy.


Design, Prototype and Experimentation

We have worked a few variations on this concept. Two versions have already been employed in a patent Method of Making Housing Components US 8,9991,137 B2 granted in March 31, 2015. Those worked with fiberglass forms in two designs which used the distortion in two planes (often called shell construction) with a trapezoid version and a dome version.

From the Patent:



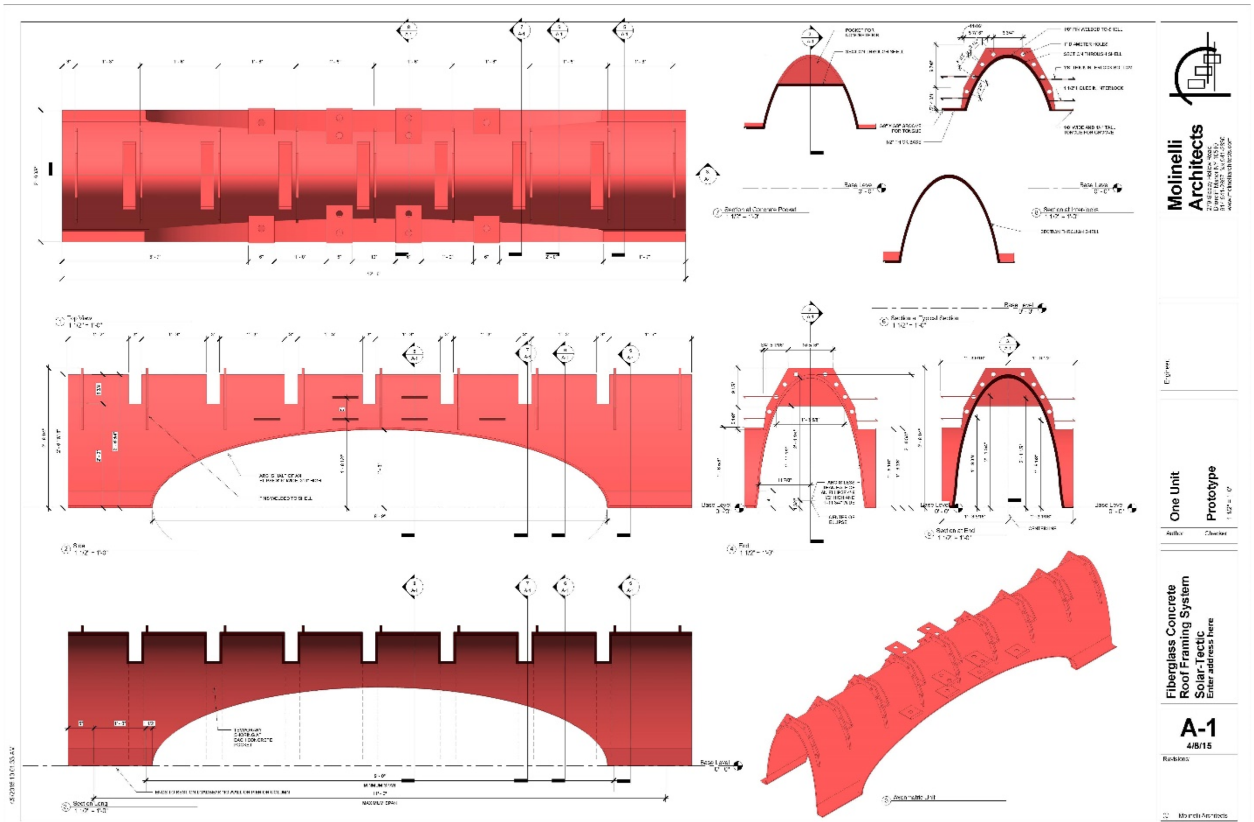


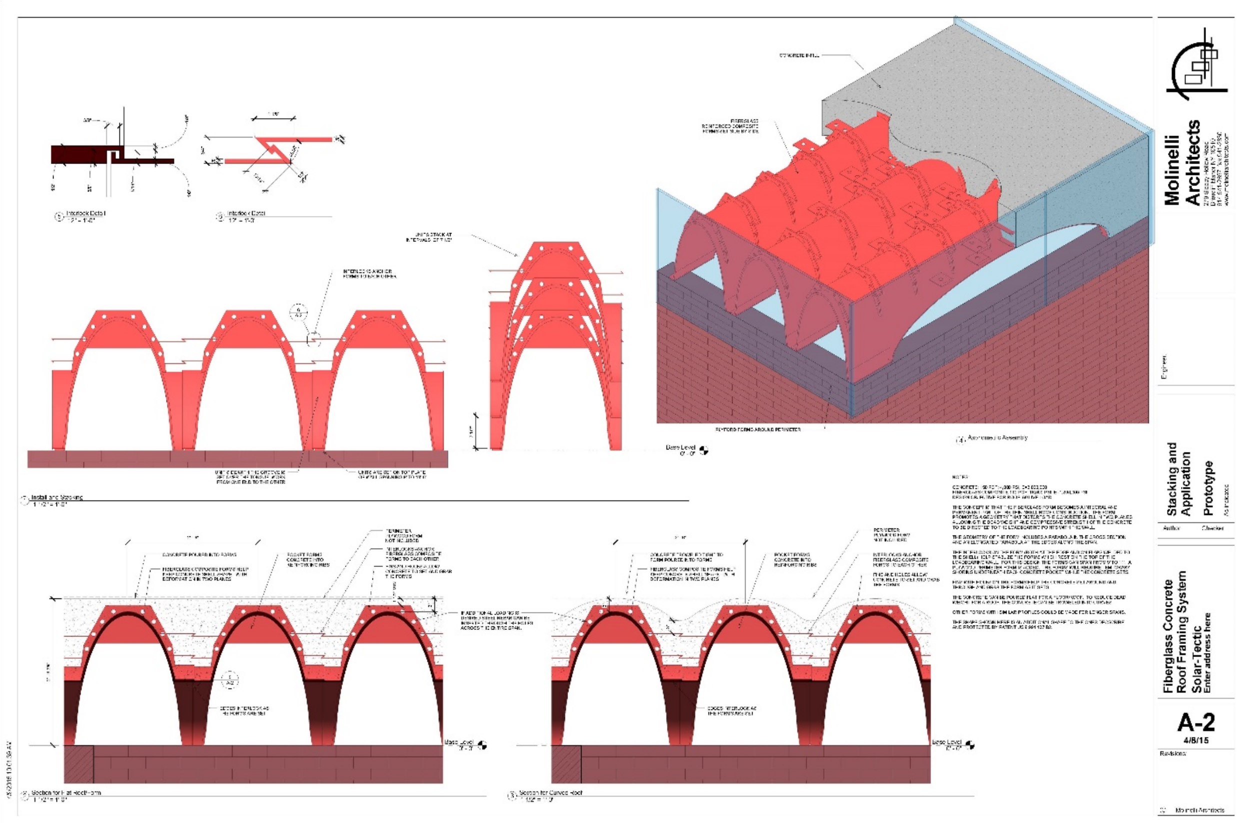
A third version, receiving a separate patents US D773,696 S published December 6, 2016 and US 2017/0268242 A1, published September 21, 2017, changes a fundamental aspect of the previous design which had assumed the fiberglass formwork could achieve tensile strength significantly greater than the concrete itself. In this version, the formwork is deeper so that the concrete is working more in compression and less reliant on the tensile strength of the form. It also introduces the possibility of thermoplastic being used for the formwork.

The idea is based then on these general properties of materials:

MATERIAL	COMPRESSIVE STRENGTH psi	TENISLE STRENGTH psi	MODULUS OF ELASTICITY psi	DENSITY pcf
Concrete	4,000 *(19,530 k/m^2)*	500 *(2,441 k/m^2)*	3,600,000 *(17,576,739 k/m^2)*	150 *(2,403 k/m^3)*
Steel	36,000 *(175,767 k/m^2)*	70,000 *(341,770 k/m^2)*	29,000,000 *(141,590,401 k/m^2)*	483 *(7,737 k/m^3)*
Fiberglass (70%Egb)	135 *(659 k/m^2)*	805 *(3,930 k/m^2)*	1,200,000 *(5,858,913 k/m^2)*	112 *(1,794 k/m^3)*
Plastic (nylon 6)	12,000 *(58,589 k/m^2)*	13,000 *(63,472 k/m^2)*	1,800,000 *(8,788,370 k/m^2)*	83 *(1,330 k/m^3)*

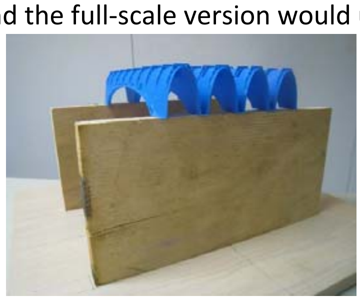
The following are proto-type drawings of the new form:

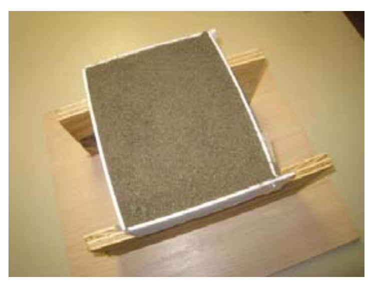




To test the ideas, we had 1/24 scale models of the form made in plastic (nylon 6) on a 3d printer. Then assembling as we would in the field we poured concrete on the form. This gave us a platform of 6 x 8 inches *(15.2 x 20.3 centimeters)* or about 1/3 of a square foot (*0.031* m^2).

The logic of scaling up the results must be scrutinized. Considering what is happening on the molecular level the 1/24 scale would seem an insignificant magnitude difference particularly since both the model and the full-scale version would ultimate act monolithically.







After 28 days of curing time we loaded the floor with 10 pounds (a weight) and 7 ounces (the wood blocking) for a total of 10.44 pounds *(4.73 kilograms)* which gave us the equivalent of over 30 psf (*146 kilogram-force per square meter.*) After 4 weeks, the load has held without cracking or failure.

Week 1: Loaded 10.44 pounds *(4.73 kilograms)*

Week 4: Added 5 pounds – total 15.44 pounds *(7.00 kilograms)*

Week 6: Add 5 pounds – total 20.44 pounds *(9.27 kilograms)*


Week 9: Added 10 pounds – total 30.44 pounds *(13.81 kilograms)*

Week 11: Added 10 pounds – total 40.44 pounds *(18.34 kilograms)*

Week 12: Added 10 pounds – total 50.44 pounds *(22.88 kilograms)*

Minor deflection as of 15 weeks.

Week 15: Added 10 pounds – total 60.44 pounds *(27.42 kilograms)*

Held 70.44 pounds *(27.42 kilograms)* for a week. Did not fail until more weight was added.

211 pounds per square foot

(1030 kilograms-force per square meter)

Week 16: Added 10 pounds – total 70.44 pounds *(31.95 kilograms)*

Week 17: Added 11 pounds – total 81.44 pounds *(36.94 kilograms)* *SYSTEM FAILED IN 4 HOURS*

The scale model of the system demonstrated that it can hold a live load of 211 pounds per square foot (1030 kilogram-force per square meter.) Whether this strength holds up to a full-scale model needs to be analyzed and tested.

CAN THESE FORMS BE MANUFACTURED AND SHIPPED ECONOMICALLY?

We do not know.

The manufacturing of plastic forms is not an expertise of ours. There are many kinds of thermoplastics and many means to form them. Our experiment used a Plastic (nylon 6) and 3D printer. An expert might be able to recommend other kinds of plastics which might lend themselves to injection molding, extrusion blow molding, vacuum forming, or compression molding. How the kind of thermoplastic and the forming technique affects cost and/or performance needs to be studied.

The shape in the more recent patent is designed to be stacked. This would reduce the space needed to ship the forms. The economics of that also needs the input of an expert. Sizes might be produced based on the most efficient use of the space inside a shipping container. Perhaps as portable 3d printers become more economical, it might be that shipping the 3D printer and raw materials to the site and producing the forms on site may make this system more viable.

WILL THE SYSTEM PERFORM IN THE FIELD AS EXPECTED?

We do not know.

Right now, the system would require temporary shoring while the concrete sets. The perimeter needs to be contained with a flat board. Both add time, materials and therefore cost to the system. The interlocking mechanicals were sufficient for our small-scale experiment but they may be more critical for a full-size operation. Can each form be handled by one person or are two needed? What happens to cracked or damage forms? Can they perform or is the material lost? All these issues need to be addressed and tested to further development of the system.

CONCLUSION

The structural concept of the Concrete Floor and Ceiling System without Steel Reinforcing is very workable. Development and research is needed to make this system a viable option in the building industry.

End of Report