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Anidolic Day-Light Concentrator of Innovative Structural Building Envelopes

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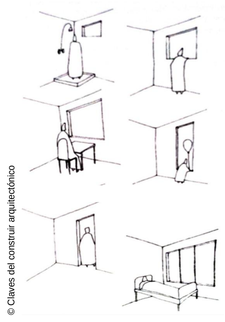
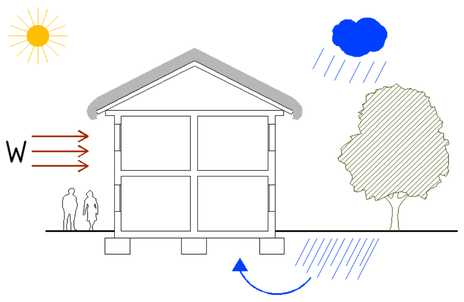
MOTIVATION

In a building, all the openings placed on its envelope (i.e. façades and/or roofs) usually have non-structural and non-insulation properties. In fact, the energy saved in a building is usually lost through these openings. Therefore, it is necessary to develop a structural element capable of being used in the building envelope and leads to light permeability from the outside to the interior of the building.



A. CONTROL OF VIEWS



B. ENVIRONMETAL CONDITIONS

MAIN OBJECTIVES

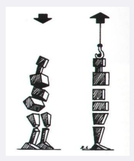
Basic research is conducted on a single panel element designed considering four simultaneous requirements which are usually set apart:

A. **Permeability** of light through the building

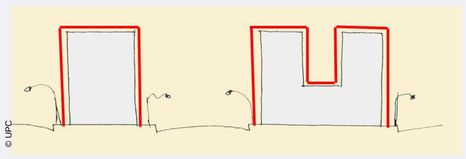
B. **Avoiding** losses and gains of energy inside the building

C. **Structural** stiffness and strength

D. **Conforming** the building envelope to construction practice



C. STRUCTURAL STIFFNESS



D. BUILDING ENVELOPE

THE PROBLEM / PROJECT BACKGROUND

A. **Permeability** of light is usually in conflict with the structural requirements, unless the elements are permeable to the light without significant loss of the structural resistance.

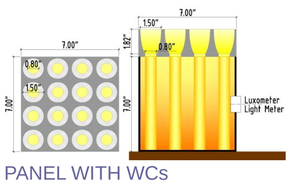
B. **Losses or gains** of energy are through the openings of the building envelope.

C. **Structural** stiffness and strength are reached through proper design of the panel, e.g. thickness and use of reinforced concrete with fibers, e.g. carbon or glass.

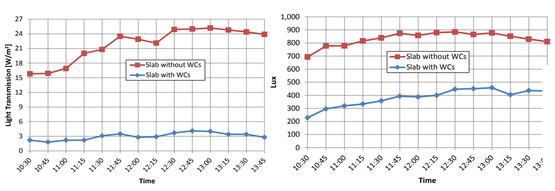
D. **Conforming** the building envelope to practice, from a pragmatic standpoint, means that:

- Cost should be as low as possible.
- No other elements are needed for finishing the envelope.
- The envelope should collaborate as a part of the structural sub-system.
- The construction procedure should be simple and scalable.
- Movable and mechanized parts are avoided.

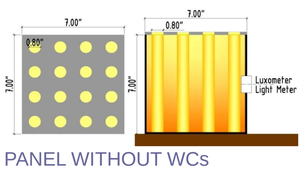
TEST 1



PANEL WITH WCs

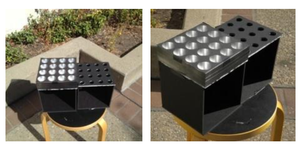


RESULTS OF TEST 1

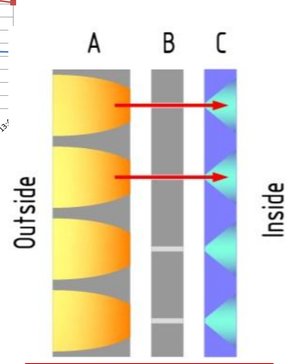


PANEL WITHOUT WCs

- Higher values were obtained from the panel without WCs. The panel with WCs had the highest results almost during the same solar time.
- The panel with WCs produced almost a constant light power throughout the whole test duration. On the other hand, the panel without WCs produced varying light power with the time of the day.



PROPOSAL

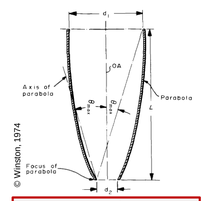


A. Light concentrating
B. Light pipe
C. Light scattering

- **Layer (A)** is made of reinforced concrete with embedded WCs to concentrate the natural sunlight from outside in a geometrical way, without mechanizing the panel.
- **Layer (B)** is made of reinforced concrete with embedded optical fibers. This layer is to stiffen and strengthen the proposed structural sub-system and to transmit the natural sunlight from outside to the building interior.
- **Layer (C)** to scatter the light in the interior of the building and to avoid glare effect.

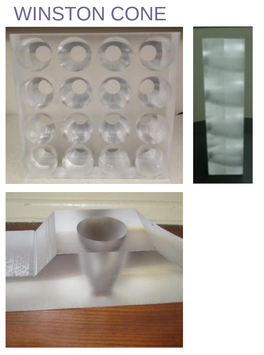
Currently, this research is only focused on **Layers A+B**

WINSTON CONE



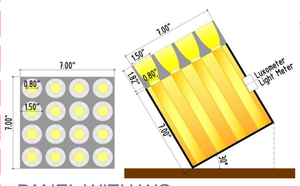
$$\sin\theta_{max} = d_2/d_1$$
$$L = (d_1 + d_2)/2\tan\theta_{max}$$
$$\rho(\phi) = 2f/(1-\cos\phi)$$
$$2\theta_{max} \le \phi \le \theta_{max} + \pi/2$$
$$f = d_2/2(1+\sin\theta_{max})$$

WINSTON CONE

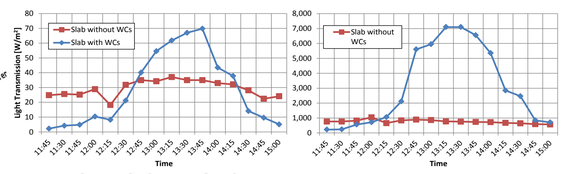


- The Winston Cone (WC) is a **parabolic sunlight collector** which has the property to concentrate the solar beams.
- The presented innovation does not avoid the need for filtering the light and controlling the energy incoming into and exiting from the building.
- Most uses of WCs have been limited to solar energy, light concentration in astronomy, and signal measurements.
- WC application in this study is novel. The study tackles new frontiers for WC uses in an **anidolic** manner for energy efficiency and sustainability of almost every building typology.

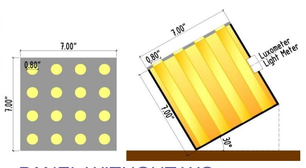
TEST 2



PANEL WITH WCs

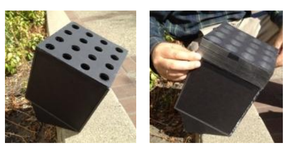


RESULTS OF TEST 2



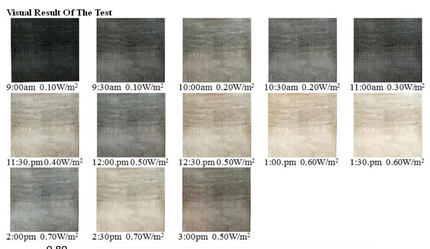
PANEL WITHOUT WCs

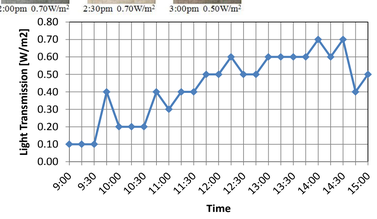
- The higher values were obtained from the panel with WCs. The luminance increased almost 7 times during one hour when using WCs with the panel in 30º inclined position. Moreover, the maximum light power per unit area in W/m² almost doubled for the panel with WCs compared to that without WCs.
- The high efficiency of the inclined panel with WCs in terms of the light power was for two hours and in terms of the luminance was for 2.5 hours.



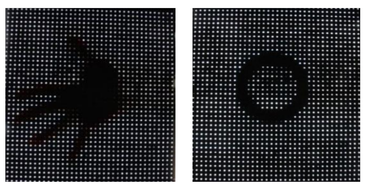
TEST 3

RESULTS OF TEST 3





The graph shows how at the time interval of sun fully irradiating (2:00 pm to 2:30 pm), translucent concrete (TC) panel demonstrated the highest results, i.e. 0.70 W/m². The results clearly demonstrate how the TC panel light transmission increases with the increase of the sun irradiation during the test duration.



DISCUSSION

The solution presented herein does not elude the need of channeling the energy, e.g. light, heat, and noise, crossing the envelope. It simply reaches the twofold goal:

- **Permeability** of light
- **Structural** stiffness and strength

From the test results (TEST 1 and TEST 2)

- The panel with WCs offers a constant amount of light during the day, with less variation than the one without WCs. Based on test findings, the horizontal positioning of the panel with WCs is not the most efficient configuration for using the WCs.
- When the panel is inclined close to the sunlight incident angle of the test location, i.e. 30° in TEST 2, use of WCs was very beneficial for light capturing.

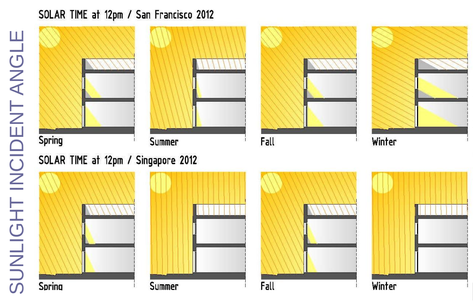
From the test results (TEST 3)

- For the tested TC panels, it is important to optimize the orientation of the panel if one seeks to maximize the light transmission from such panels.
- The optical fibers conduct the sunlight and the indirect light from outside to the interior of the building but the highest efficiency is achieved when the sunlight was irradiating the optical fiber cross-section using WCs.

FUTURE GOALS

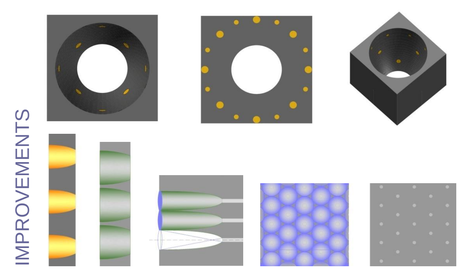
- **Testing the two-layer (cones + fibers) configuration.**
- **Numerical modeling to optimize the solution.**
- **Structural testing of the panel with WCs.**

CONCLUDING REMARKS



Explore other inclinations of specimens according to the sunlight incident angle at different locations to optimize the capabilities of capturing natural sunlight.

Explore the structural properties (stiffness and strength) of the TC panels.



Improve designed WC cross-section with the objective of collecting more natural sunlight in vertical and/or horizontal orientations without the need to incline the panel.