

**Submission Category:** Unbuilt Works

**Project Type:** Research & Development (R & D) of **SOLtek** a solar-heated kiln to cure concrete masonry units (CMU's)

**Project Address:** Our Lady of Perpetual Help Village, Plaine de Nord, Haiti (Applicable to all developing nations using CMU construction)

**Date of Substantial Completion:** In-the-field casting & curing (December 2016) / Lab testing (February 2017)

**Drawings & Photos:** See pages 5-20. Includes captions.

**Architect's Statement:** The research and development of the **SOLtek** Kiln began with a university-based, research project carried out by a team of architecture students in 2012. The class was funded by a major foundation that represents the masonry industry in the U.S.A. and Canada. Their project, **SUN TRAP**, established the conceptual bases for the subsequent phases (2013 – 2017) which were undertaken by the office of the Architect who is submitting this project and who was the instructor for the research course. Both the Architect and students will be recognized on the Award, should the project be fortunate to be deemed worthy of an award.

The jury is directed to pages 5 – 20 of this submission which contains an integrated presentation of both written descriptions, photo documentation and graphic documentation. All drawings for **SOLtek** were executed in situ and in freehand to reinforce that there is very little available electricity where the casting and testing of the kiln was carried out, thus precluding the use of computers.

The following are the critical aspects of design considerations, limitations, requirements and solutions required by the submission guidelines:

- **IMPETUS / CATALYST TO ENGAGE THIS R & D PROJECT:** The impetus or catalyst that “jump-started” this dual focused project was an event that took place on January 12, 2010. This was a catastrophic magnitude 7.0 M earthquake, with an epicenter near the town of Léogâne, approximately 25 kilometers west of Port-au-Prince, Haiti's capital. Estimates are that 75% (+/-) of the existing concrete and concrete masonry structures were damaged or destroyed. Haiti's government has estimated the death toll at 230,000 and says more bodies for which a final determination of death in future years may never be known. SOLUTION: All of the following are dependent on a BASIC VOCATIONAL EDUCATION PROGRAM THAT WOULD BE CONDUCTED IN-THE-FIELD BY HAITIAN EDUCATORS accompanied by the architect/educator who is principal investigator on this project and an interpreter.

- **DEFICIENCIES IN CMU CONSTRUCTION BECOME READILY APPARENT:** The educator/practitioner's earliest experiences (2001-2003) involved him and students in mission work in Haiti working alongside local masons in constructing (mixing "concrete," casting CMU's and laying them for) prototype latrine projects and a K-6 school. This was followed by his experiences as project designer and manager with his architectural practice that took on five projects in Haiti pro bono. Four of the five buildings that were / are being constructed between 2011 and the present used the traditional reinforced concrete frame and CMU in-fill construction system. These experiences made him painfully aware of the incredible deficiency in the quality of the materials used in CMU manufacturing and construction: (dirty water (\*); non-graded-for-size, unwashed "river sand;" a cement /sand ratio of up 15 to 1 +/-; and **NO CURING OF THE CAST BLOCK UNITS** except for having them dry in the sun. Added to the deficiencies of mixing and casting process ...either using a single, hand-packed block mold on the ground or two block, manually operated, block-making machine is the almost total lack of skills of a majority of masons in rural communities. quality control in the majority of concrete masonry construction due to the lack of knowledge and skills of the majority of Haitian masons active at present in construction.
- **INITIAL PHASE UNDERTAKEN BY ACADEMIC, RESEARCH CLASS:** The Architect (architectural educator / practitioner) for the **SOLtek** kiln was the studio/class instructor for the team of architecture students who undertook the initial R & D of a solar kiln that they named **SUN TRAP**. Since then his firm has taken on this project with his time being donated through their pro bono service initiative. During this last trip in December 2016, he conducted the latest round of casting, curing and testing of the initial small scale prototype of **SOLtek**. His firm plans to continue to develop the project with a half-scale model that will accommodate twenty (20) half-scale blocks that is planned to be built and tested in Haiti during 2017.
- **LIMITATIONS:** The limitations that the R & D team faced were those encountered in any research project ... both pure and applied ... dealing with materials and methods of construction in developing countries.

  - **TIME COMMITMENT GIVEN PRO BONO FORMAT:** To get to the sites in Haiti where the R & D was carried out takes one, full day each way of travel plus needing to spend the required 48 hrs. (2 days) in order to ascertain the desired research findings. Thus, four (4) days is the minimum time commitment for each visit and research trial.
  - **OPTIMIZE TIME IN-SITU IN HAITI:** These included making the most of the time actually spent by the Project Director / Chief Researcher on construction sites in Haiti during or immediately after actual construction took place. This afforded photo-documented proof of the poor construction materials and methods of construction that cannot be easily ascertained once the structures are covered in stucco ... thus giving the appearance of buildings of sound construction.
  - **REPLICATE THE ACTUAL ENVIRONMENTAL, CLIMATE, MATERIALS CASTING AND SITE CONDITIONS FOUND IN HAITI.** The only feasible way to accomplish this was to undertake in-situ testing in Haiti whenever possible (see limitation No.1., above) ...with the most current testing results of the **SOLtek** kiln taking place in December of 2016.

- **CHALLENGED TO DEVELOP A COMPREHENSIVE SOLUTION THAT:**
- **1. recognizes that a majority of CMU production in Haiti in the foreseeable future would remain a “cottage industry” ... especially in smaller towns and rural areas;**
- **2. would be understandable (w/ a minimum of education/training) to the common CMU production culture and masonry trade;**
- **3. would be affordable so that the common CMU production culture and masonry trade could afford to implement with minimum financial assistance;**
- **4. would address and remedy the major liabilities currently found in the CMU casting process in Haiti ... that of:**
  - 4.A. inferior strength block caused by poor quality control of materials;**
  - 4.B. the cast units being placed on ground to dry/cure, thus having the bottom of the unit with an uneven surface and imbedded with small stones and earth; and,**
  - 4.C. the lack of the critical step of curing in the production process;**



**SOLUTION:** All of the following are dependent on a **BASIC VOCATIONAL EDUCATION PROGRAM THAT WOULD BE CONDUCTED IN-THE-FIELD BY HAITIAN EDUCATORS** accompanied by the architect/educator who is principal investigator on this project and an interpreter.

**1.0. The IMPROVEMENT IN THE QUALITY OF THE MIX THROUGH ... teaching simple methods to ensure:**

**1.A. THE STRICT MONITORING OF CEMENT/SAND/AGGREGATE RATIOS**

**1.B. “GRADING SAND AND AGGRGATE W/ SIMPLE SIEVES**

**1.C. OBTAINING “POTABLE” WATER BY CATCHING & STORING RAIN water**

**2.0. The DEVELOPMENT OF SOLtek ...** a simple, low tech, solar-heated kiln ...so as to include a curing step that would add substantially to the compressive strength of the manufactured (cast) block units.

**RESULTS TO DATE:** The latest testing of the **SOLtek** Kiln proved that, in concept, this piece of equipment used in a prescribed manner to ensure optimum results **SIGNIFICANTLY INCREASED THE COMPRESSIVE STRENGTH OF THE CMU’s.**

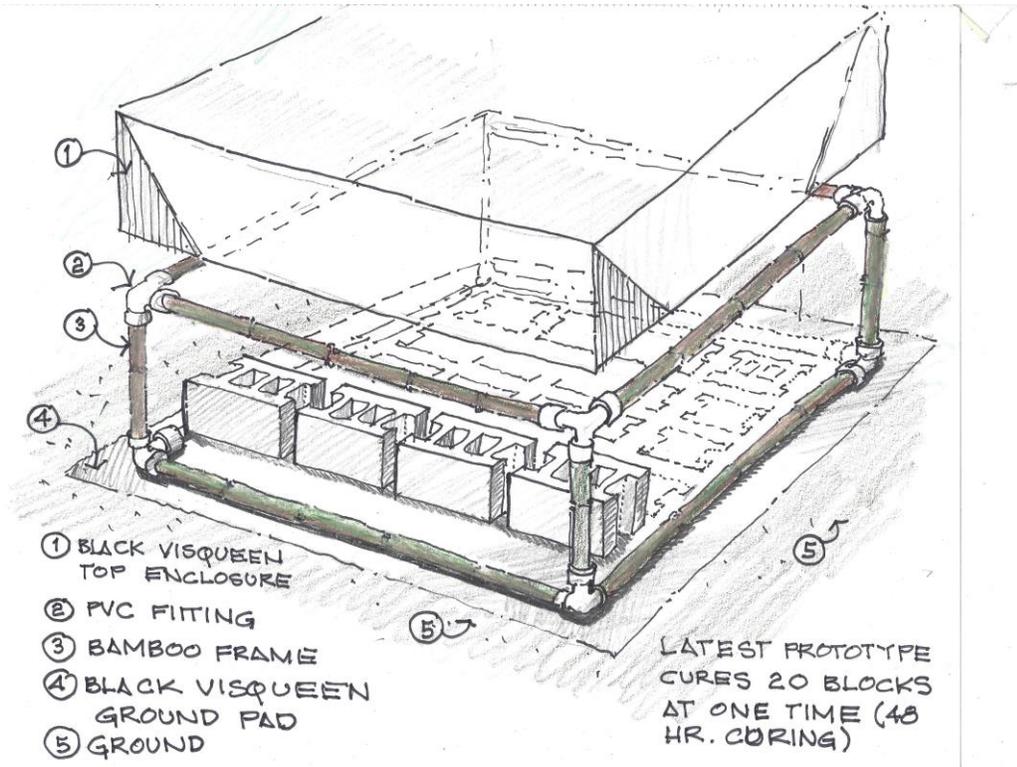
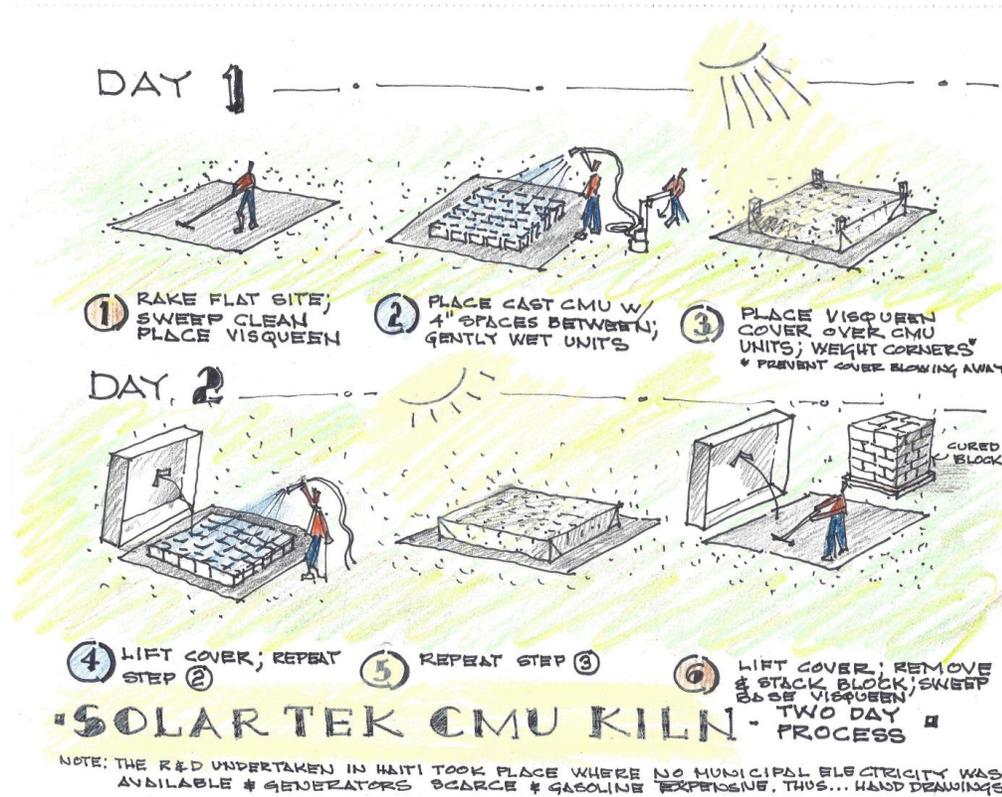
**NEXT PHASE OF TESTING** will involve a half-scale mock-up of a 20 UNIT **SOLtek** kiln. Half-scale blocks will be cast in Haiti, cured in the SOLtek kiln and several will be tested for their compressive strength. The remainder will be used in a mock-up of a portion of a wall and tested for resistance to lateral loads.

**SHORT-TERM ASSESSMENT:** It is apparent that a sustained program that combines vocational education with in-the-field apprenticeships for masons must be established on a national scale but focused at the local level as CMU production will remain a “cottage industry” in Haiti and other developing countries for the foreseeable future.

**LONG-TERM ASSESSMENT:** In addition, it is also apparent that modern-day, masonry material supply industry, block and cement manufacturing plants, concrete batching facilities and transport capabilities must be developed according to a national plan that will guarantee availability to all regions but with regulations to guarantee affordable prices to local mason contractors.

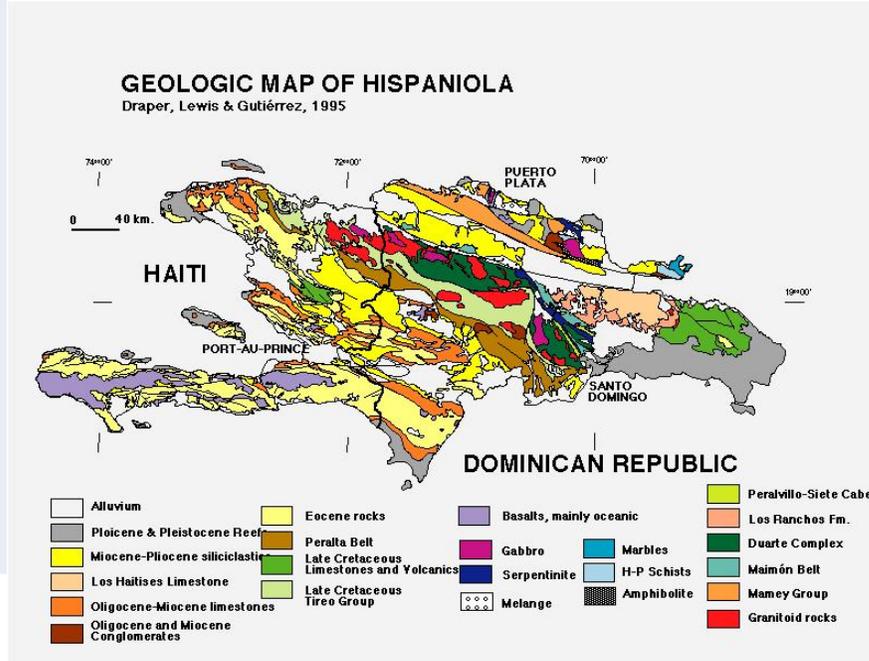
# Research & Development of **SOLtek**

A solar-heated kiln to cure concrete masonry units (CMU"s) and increase their strength



# IMPETUS

The impetus or catalyst that “jump-started” this dual focused project was an event that took place on January 12, 2010. This was a catastrophic magnitude 7.0 M earthquake, with an epicenter near the town of Léogâne, approximately 25 kilometers west of Port-au-Prince, Haiti's capital. Estimates are that 75% (+/-) of the existing concrete and concrete masonry structures were damaged or destroyed. Haiti's government has estimated the death toll at 230,000 and says more bodies for which a final determination of death in future years may never be known.



## **OBVIOUS PROBLEMS GAIN THE ATTENTION OF THE INTERNATIONAL DESIGN / ENGINEERING / CONSTRUCTION COMMUNITY:**

**The devastating failure rate as a result of the lateral seismic forces on the structural integrity of the majority of structures in Port-au-Prince and its environs confirmed what anyone involved in the design, engineering and construction of cast-in-place concrete and concrete masonry systems already knew. That is ... the lack of any building code coupled with the total lacking of any quality control as it applies to both the materials used and methods of construction of these two systems led to the inevitable total collapse or severe compromise of their structural integrity.**



## PRIOR / CURRENT INVOLVEMENTS:

The architectural educator / practitioner who is the studio instructor for the team of students who undertook the initial R & D of the SUN TRAP has made 23 trips to Haiti since 2001 with the latest being in December of 2016. During this trip he conducted the latest round of casting samples and curing them in the small scale prototype of **SOLtek**, the solar heated kiln his firm is developing. During these trips he also developed masonry skills (right) and communication skills through sketches & language with the help of an interpreter (below).



## PROF. EXPERIENCES: - Cont.

Since 2006, his sole-practitioner firm has been the urban designer/architect for six (6) projects in Haiti. Among them are the Campus Plan for the Orphanage Village of Our Lady of Perpetual Help (OLPH) - Completed: 2013 / Revised 2015 (below) and Residential Complex of Our Lady of Perpetual Help - First unit opened in September 2016; K-6 School at the OLPH Campus – partially completed and in use in fall 2016;



## DEFICIENCIES IN CMU CONSTRUCTION – Continued:

All of the aforementioned experiences led the project director to conclude that **THE SINGLE MOST OBVIOUS LIABILITY IN THE CURRENT MANUFACTURING PROCESS OF CMU'S IN HAITI IS THE LACK OF ANY CURING OF THE CAST BLOCK UNITS** except for having them dry in the sun (right). The blocks that result have little strength as witnessed by them being able to be easily broken by hand (below).





**Initial investigation of R & D of a solar-heated kiln carried out by a team of architecture students who develop SUN TRAP in the fall semester of 2010. Students assemble prototype (left/above) & present their project (right/above).**

## SUN TRAP

### Attraper le Soleil

**FOUNDATION**

### ASSEMBLY

CMU | Kiln | Ergonomics

The kiln sits on the ground.

Scrapscum be used for to place the CMU inside and remove.

A solar oven adds moisture.

## SUN TRAP

### Attraper le Soleil

**FOUNDATION**

### Research & Development

teapot | pressure

After a teapot fills with steam, a valve releases due to pressure to release steam into a room. Current steamers use the same technology, releasing a concentration of steam depending on the volume of the apparatus.

humidifier | wicking

One of Wick's humidifier models includes wicking technology pulling moisture up through fabric. Some have claimed to add heat and moisture a room with homemade wicking technology, more tests are needed to determine the exact benchmark of the technology.

sauna | hot rocks

In a room that is roughly 64 square, pouring water on heated rocks could fill a room with steam.

solar oven | reflection

A lighting professor at Ball State University gave evidence that solar reflecting materials can heat liquids so well that one could use such an apparatus to cook soup after eight hours time.

fresnel lens | prism + light

The same professor determined that directing light through the prism of a fresnel lens could cook an egg in just a few minutes.

stacking structure | wicking

light structure | solar heating

modular unit | solar oven heating

modular unit | sunlight + prism

raw material	\$	unit	\$	unit	\$	unit	\$
4 (1/2") PVC Pipe	\$1	8 (1/2") PVC Pipe	\$2	8 (1/2") PVC Pipe	\$4	one unit	\$11
2 (2 1/2") PVC Pipe	\$1	3 (2 1/2") PVC Pipe	\$1	4 (2 1/2") PVC Pipe	\$2	two units	\$19
2 (2 1/2") PVC Pipe	\$1	4 (2 1/2") PVC Pipe	\$2	8 PVC fittings	\$1	three units	\$27
4 PVC fittings	\$1	8 PVC fittings	\$2	2 pieces of reflective material	\$1		
2 pieces of reflective material	\$1	2 pieces of reflective material	\$2	2 bowls for water	\$1		
1 bowl for water	\$1	2 bowls for water	\$2	3 shower curtains	\$1		
1 shower curtain	\$1	2 shower curtains	\$2	3 shower curtains	\$3		
velcro	\$1	velcro	\$2				

Initial investigation of R & D of a solar-heated kiln carried out by a team of architecture students who develop SUN TRAP in the fall semester of 2010. Final presentation boards (above).

**1.0. The IMPROVEMENT IN THE QUALITY OF THE MIX THROUGH ...  
teaching simple methods to ensure:**

**1.A. THE STRICT MONITORING OF CEMENT/SAND/AGGREGATE  
RATIOS (Right)**

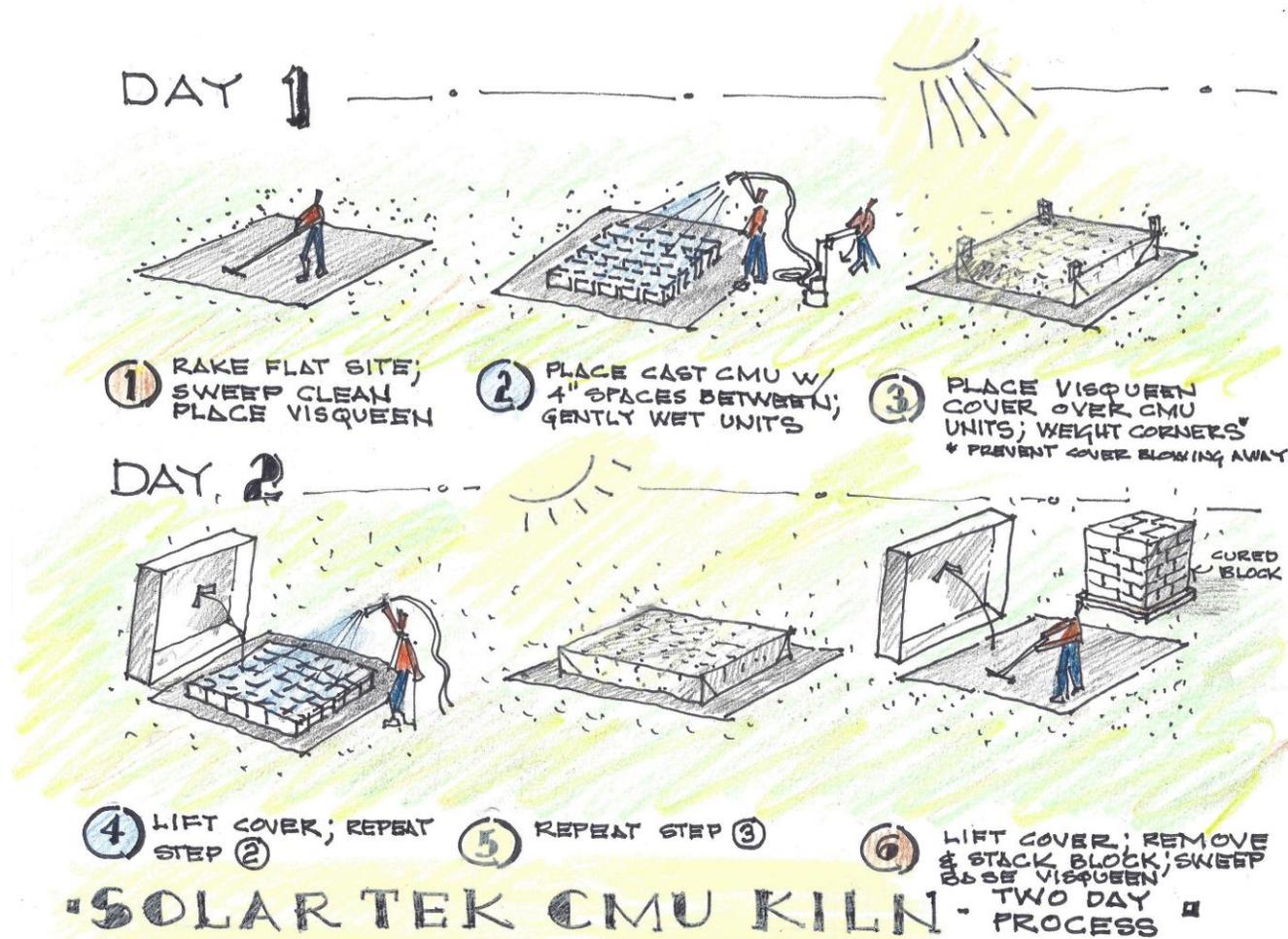
**1.B. GRADING SAND AND AGGRGATE W/ SIMPLE SIEVES  
(Below/right)**

**1.C. OBTAINING "POTABLE" WATER BY CATCHING & STORING RAIN  
WATER (Below)**



# Research & Development of SOLtek

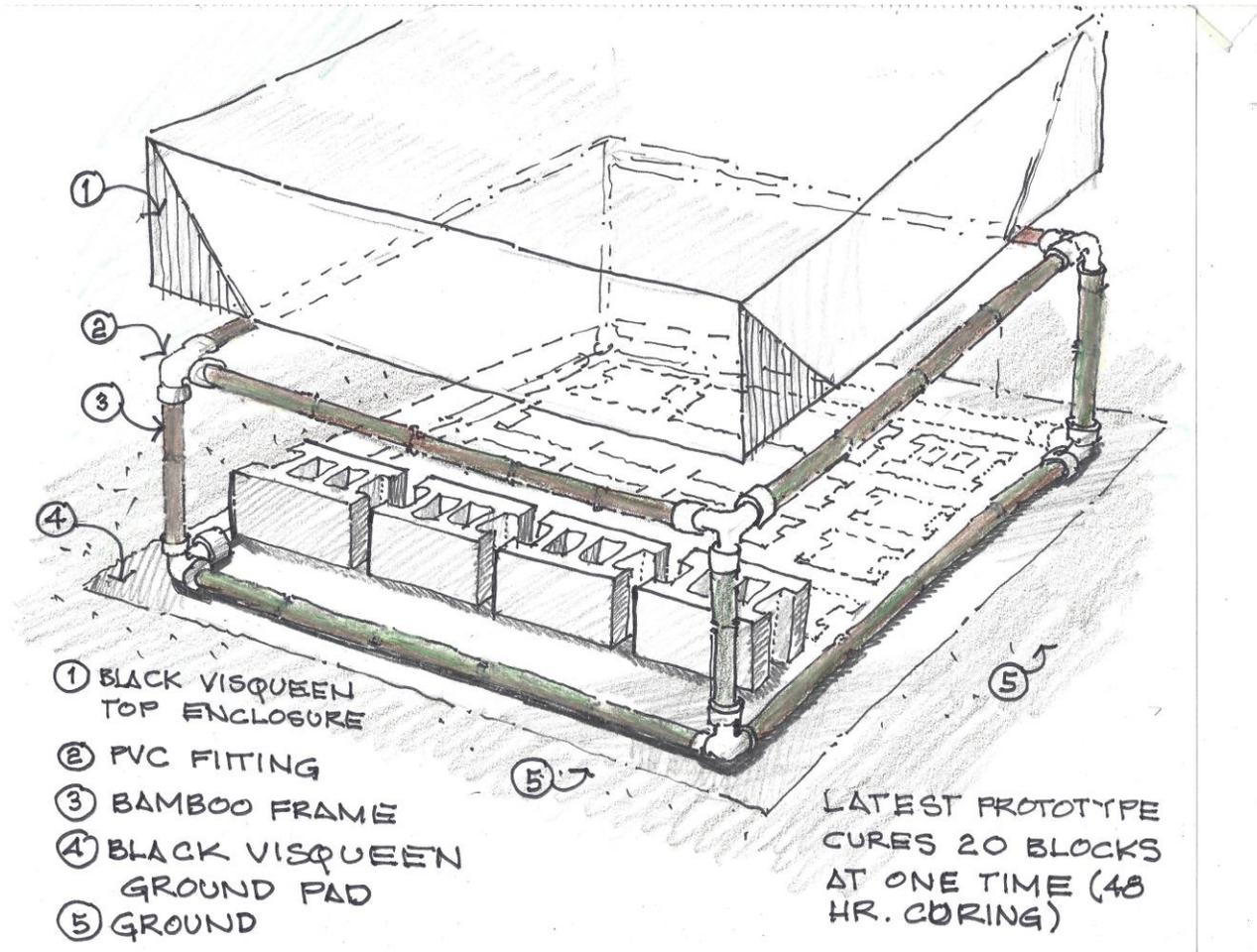
A solar-heated kiln to cure concrete masonry units (CMU's) and increase their strength

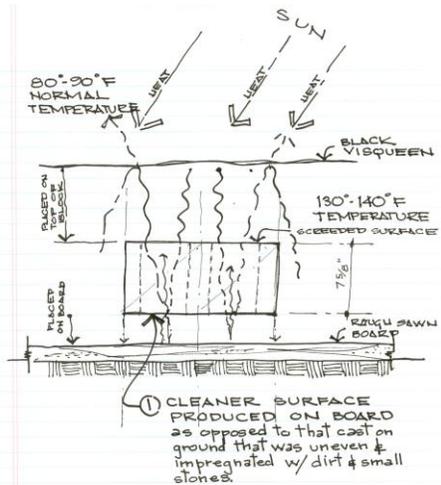


NOTE: THE R&D UNDERTAKEN IN HAITI TOOK PLACE WHERE NO MUNICIPAL ELECTRICITY WAS AVAILABLE \* GENERATORS SCARCE \* GASOLINE EXPENSIVE, THUS... HAND DRAWINGS.

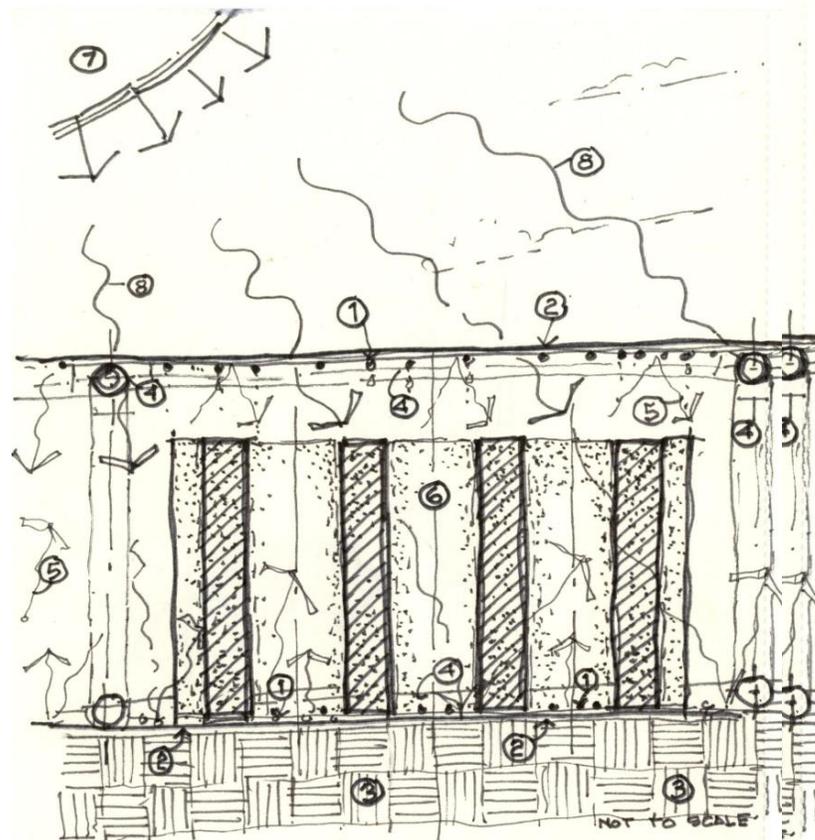
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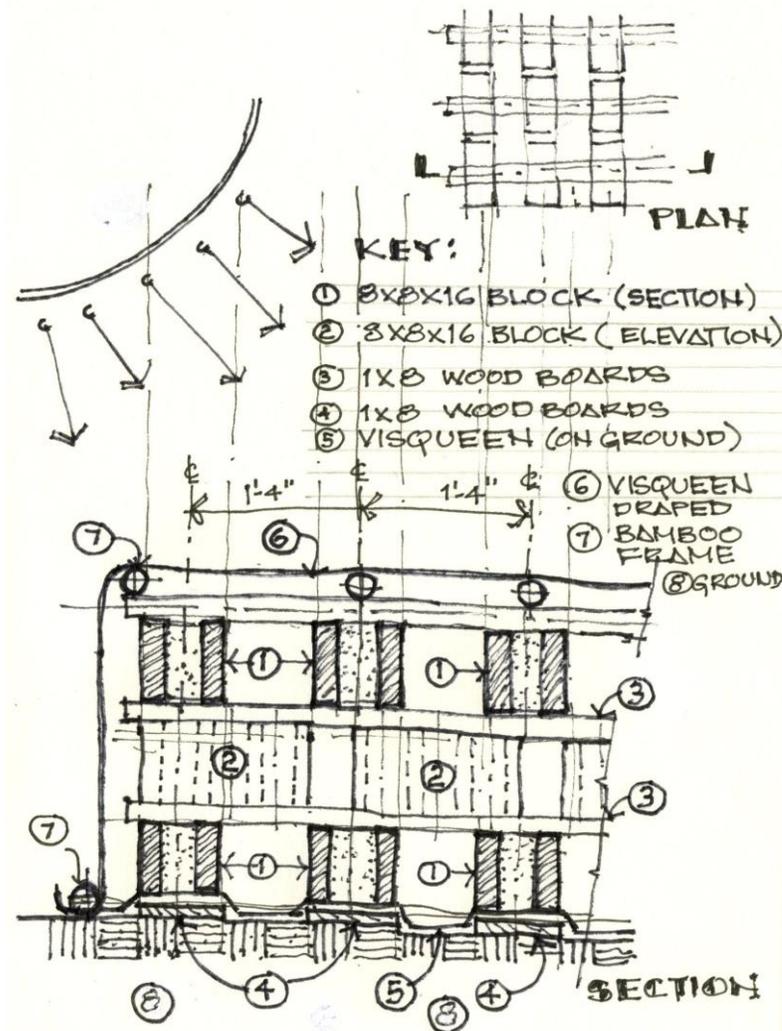


SECTION - IMPROVEMENTS in IMPROVING STRENGTH & QUALITY IN CMU'S MADE in HAITI (or any Third World country)



TYPICAL SECTION - THERMODYNAMIC / ENERGY FLOW

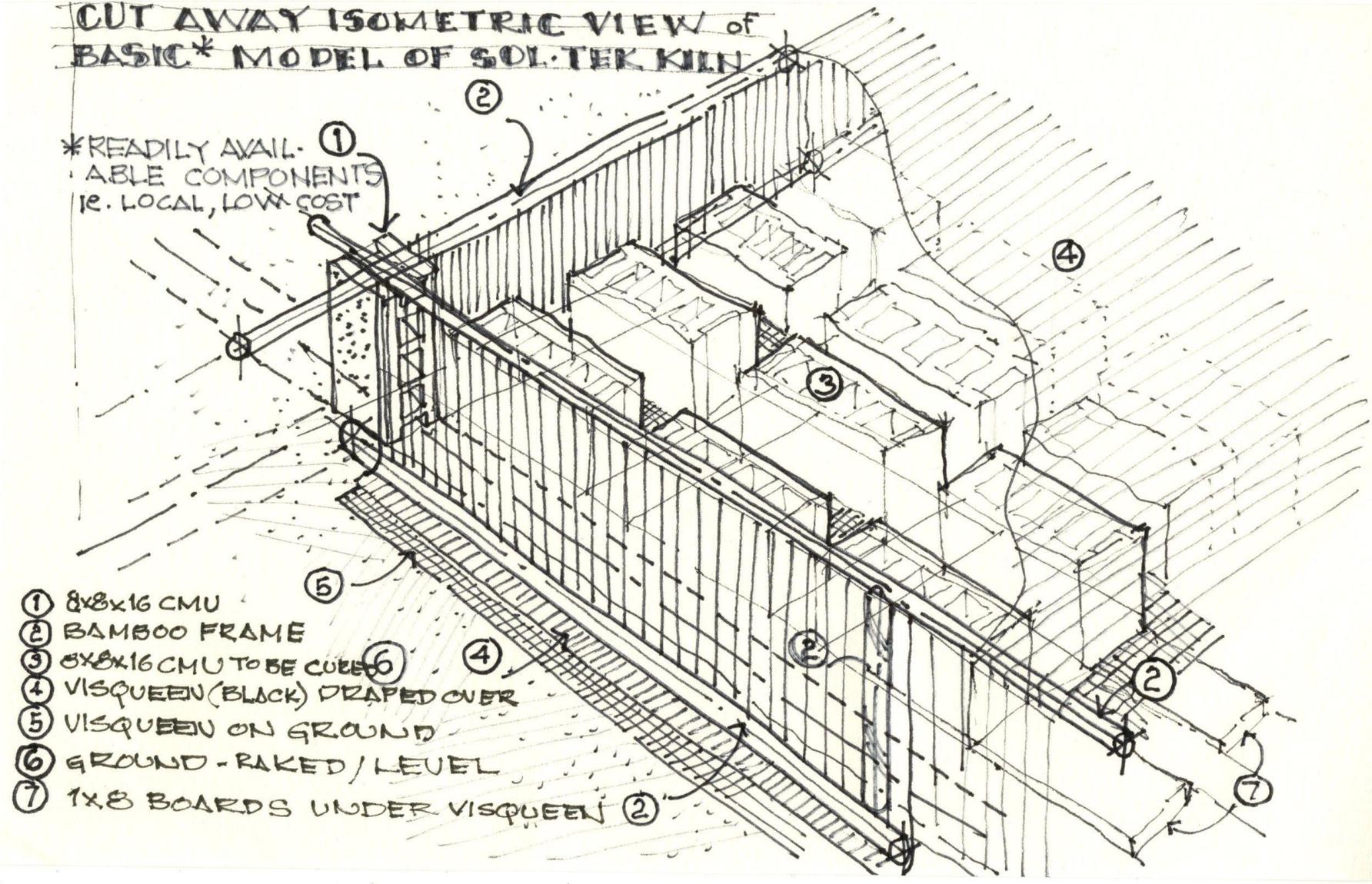
- ① CONDENSED MOISTURE
- ② BLACK VISQUEEN (MEMBRANE)
- ③ EARTH (LEVELLED SOIL)
- ④ FRAME
- ⑤ MOISTURE VAPOR
- ⑥ CONCRETE BLOCK
- ⑦ SUN (HEAT SOURCE)
- ⑧ RADIANT HEAT
- ⑨
- ⑩ MOISTURE VAPOR



SOLTEK KILN - R&D OF STACKED UNITS TO INCREASE PRODUCTION

CUT AWAY ISOMETRIC VIEW of  
 BASIC\* MODEL OF SOL-TEK KILN

\*READILY AVAIL-  
 ABLE COMPONENTS  
 i.e. LOCAL, LOW COST



- ① 8x8x16 CMU
- ② BAMBOO FRAME
- ③ 6x8x16 CMU TO BE CURED
- ④ VISQUEEN (BLACK) DRAPED OVER
- ⑤ VISQUEEN ON GROUND
- ⑥ GROUND - RAKED / LEVEL
- ⑦ 1x8 BOARDS UNDER VISQUEEN



**Small scale test kiln – Kit of parts using PVC & plastic bags**



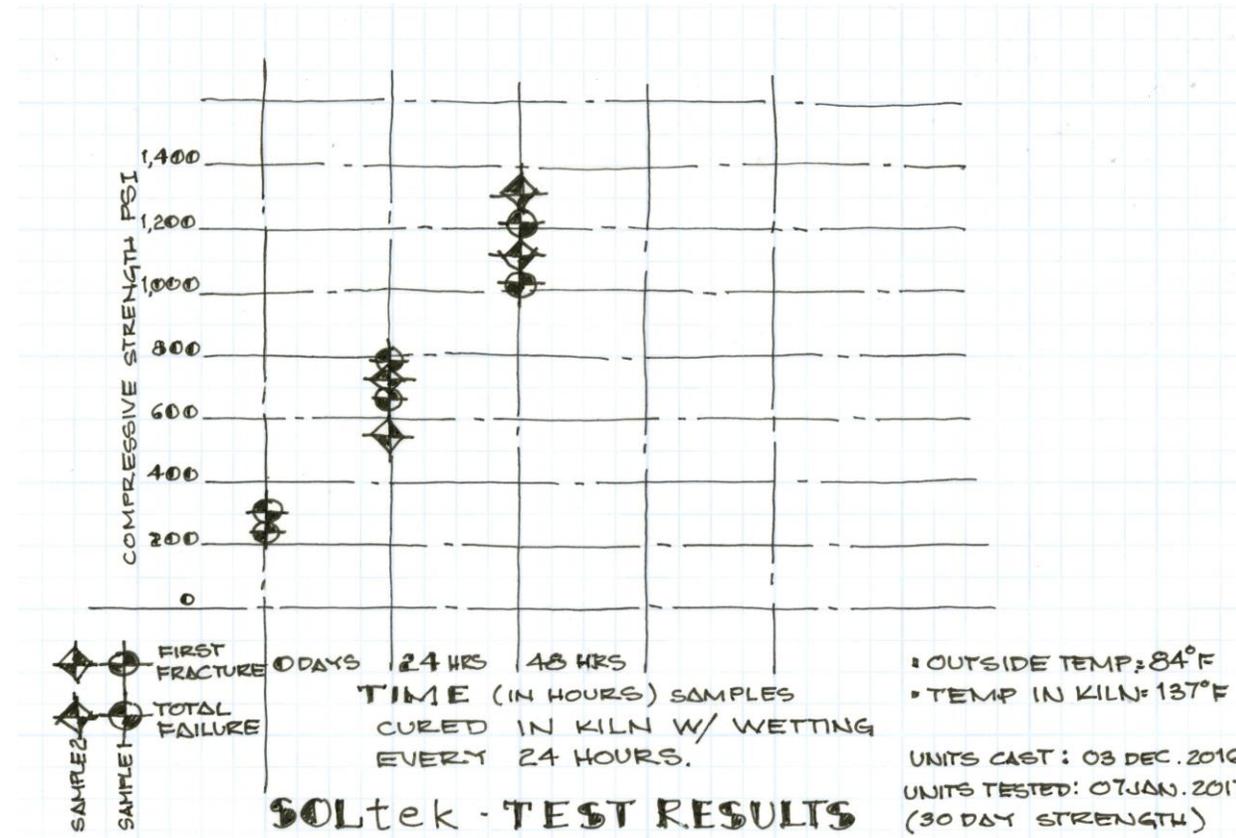
**Small scale test kiln – Assembled w/ test containers under**



(L to R) Haitian research assistant working sieve; mixing measured amounts of cement and sand; compacting samples; cast units with core forms still in inserted;; and, cast units with time (hours) of curing in kiln indicated. cast forms within and outside test kiln; and testing

# The DEVELOPMENT OF A SIMPLE, LOW TECH, SOLAR-HEATED KILN

so as to include a curing step that would add substantially to the compressive strength of the manufactured (cast) block units



Samples tested to initial fracture (top/left) and total failure (bottom/left)