Humane Infrastructure Development System H.I.D.S.

HIDS is a system designed to provide basic infrastructure needs to the lowest income 500,000,000 people on the Earth.

It is a modular system made from laminated concrete panels fabricated from cement, sand gravel, wire mesh and repurposed carpet.

This system can be used to create shelters, water filters, septic systems and more.

Philosophy.

Many aid groups give aid in forms that **are not**

Culturally appropriate
Made in the local community
Robust so as to stand up to moderate wind or seismic loads
Long lasting
Using community skill sets

We have designed HIDS to be all of these things, and more…

Why these materials?

Sand and gravel are locally available in most regions of Haiti and the world.

14 gauge galvanized steel mesh

- Less expensive than rebar
- Galvanized for long life
- Gives panels tensile strength
- Allows panels to be fastened together every 5 cm as desired.
- Allows for *plastic* deformation under extreme load conditions.
- Allows for construction tolerances of +/- 3 cm
- Can be cut with pliers
- Can be twisted together by hand to attach panels together

The wire mesh comes in 100' rolls and can be cut with pliers. The modular pieces above are stacked ready for use in making panels

Cement

Is manufactured in Haiti and most countries in the world.
Has a carbon foot print, so HIDS is designed to minimize its use.
The panels are only 4 to 5 cm thick.
Will last for many years, so the life cycle environmental costs are minimized.
Many low income communities have the skill set to work with concrete.
Can be patched with new skim-coat as erosion occurs to extend life of structure.

Carpet

Each year the USA throws out 7 trillion pounds of used carpet.
Almost none of this is repurposed or recycled.
Has great strength in the backing layer and bonds well to concrete.
Gives the panels both tensile strength.
Allows for *elastic* deformation under extreme load conditions.
Is easy to cut to fit in the forms.
Can be kept out of land fills and put to use.
Is only needed in the larger panels.

The panels

Are made in wooden forms
By pouring the concrete panels flat on the ground, minimal forms are needed.
The forms can be taken off and reused in 4 hours.
The wooden forms can be made locally with basic carpenters skills.

The forms have been designed so that no power tools are needed to use them
The forms with minimal care should last for many years.

The panels

Have been tested for strength
The compressive strength of the system is in the angled joints between sets of panels
This is similar to the added strength of “angle iron”
The compressive crush load of the angled joints has been measured at 10,000 pounds
The joint crushed, but did not fail

The panels with carpet in them are elastic and deform under catastrophic stress, but do not fail.
They crack but maintain > 80% of their initial strength under 10 degrees on bending
When the load is removed the panels mostly return to their initial state.
This allows for structures under destructive loads to deform, but then redistribute loads.
The panels were tested both in the engineering lab at UVM, and also by Hurricane Matthew.
The tensile strength of the joints is calculated based on the number of wires attached across the joint
There is a wire connection every 5 cm along the length of the joint.
The tensile strength of the steel wires is 700 lbs, but lets assume only 500 lbs.
This gives a tensile strength of 10,000 lbs per meter of joint.

After a 2 cm layer of concrete is places in the forms, the wire mesh is added. If the panel was larger a layer of carpet would be added as well. The plastic is used as a parting layer and can be reused. Note that the form boards are held in place by wiring them together at the corners. A finished panel is allowed to cure for 48 hours before being moved.

The circular foundation is leveled and ready for wall placement.

Wire joints are connected every 5 cm. The joints will be filled with concrete to secure the wires.

Rubble ballast being placed in central pit to secure structure to the ground

She stands between the ruin of her old home, and her future.

Structural design
Hurricane Resistant

One and two story domes are shapes that offer the least wind resistance during hurricanes.

The circular footprint of the domes helps with both wind resistance and also wind direction. It is equally strong from any direction. Rectangular buildings are not.

The modular design allows for radial buttresses at every joint between wall panels.

The flat roof section allows for the entire structure to have added strength for lateral loads at that elevation.

The external ribbing on the roof provides strength and protection from flying debris.

The horrible truth is that even if a structure can survive hurricane wind loading, tornadoes often accompany hurricanes.

Both tornados and flying tree trunks will destroy almost any structure.

One purpose of the HID dome is to protect people from flying debris such as sharp fragments of sheet metal roofs.   During Hurricane Matthew the dome served this purpose and did not fail.

Earth quake Resistant

One and two story domes are shapes that offer good design resistance during earthquakes.

The circular footprint of the domes helps with both earthquake resistance and wave direction. It is equally strong from any direction. Rectangular buildings are not.

Unlike most masonry, the HIDS design may deform but should not totally fail during moderate seismic loads.

Photo taken after Hurricane Matthew. The classroom dome sheltered people and survived

Reduced Masonry Design

Most building have massive poured concrete foundations
to with stand extreme load conditions.
To reduce costs and still secure the structure against dynamic loads,
The building is made “earthfast” using a rubble base.
A perimeter foundation is built and then the wall panels are placed.
The center is dug out and the walls are wired to mesh
extending down into the central pit.
This mesh is given a coat of concrete to protect it, and then back filled
with rocks and rubble.
The finished concrete floor is poured on top of this rubble.

The HIDS Structures

We have currently built two different size buildings. One is the 16 sided classroom and the other is an 8 sided Haitian Kitchen. Both can function as storm shelters, and have wall panels 120 cm in length with radial buttresses.

The Haitian Kitchen Design

Cost $1,200
8 sided
3.2 m diameter
Area 8 m^2
Roof access for water collection
Storm shelter
Can be used as small house, kitchen or store
Current status: 7 built, three more in planning

The first photo above shows where my friend cooks while her new kitchen is being built in the background. Many women cook in conditions like the ones shown above. One goal of the Kitchen project is to give the women a safe secure place that is “theirs.”

A brand new Haitian Kitchen - Storm Shelter

The Haitian House Design

Cost $2,200
12 sided
4.8 m diameter
Area 18.1 m^2
Roof access for water collection
Storm shelter
Two floor option available using wooden floor joists
Can be used as house or store
Current status: in planning, uses same wall system as Kitchen Design

HIDS Classroom Design

Cost $6,000
16 sided
6.4 m diameter
Area 32.2 m^2
Roof access for water collection
Storm shelter
Two floor option available using wooden floor joists
Can be used as house, class room or business
Current status 1 built, more in planning, new ones will use same wall system as Kitchen

Photo taken two days after Matthew.

Ease of construction

The modular panels are light enough so that two people can easily place them
These are all of the panels needed to build a Haitian Kitchen.

Roof panels put in place.

Joints are filled with concrete.

The system takes a six person crew 2 days to make the panels, and 2.5 days to erect the structure. The panels must cure for 28 days prior to construction.

The crew level the lower buttresses

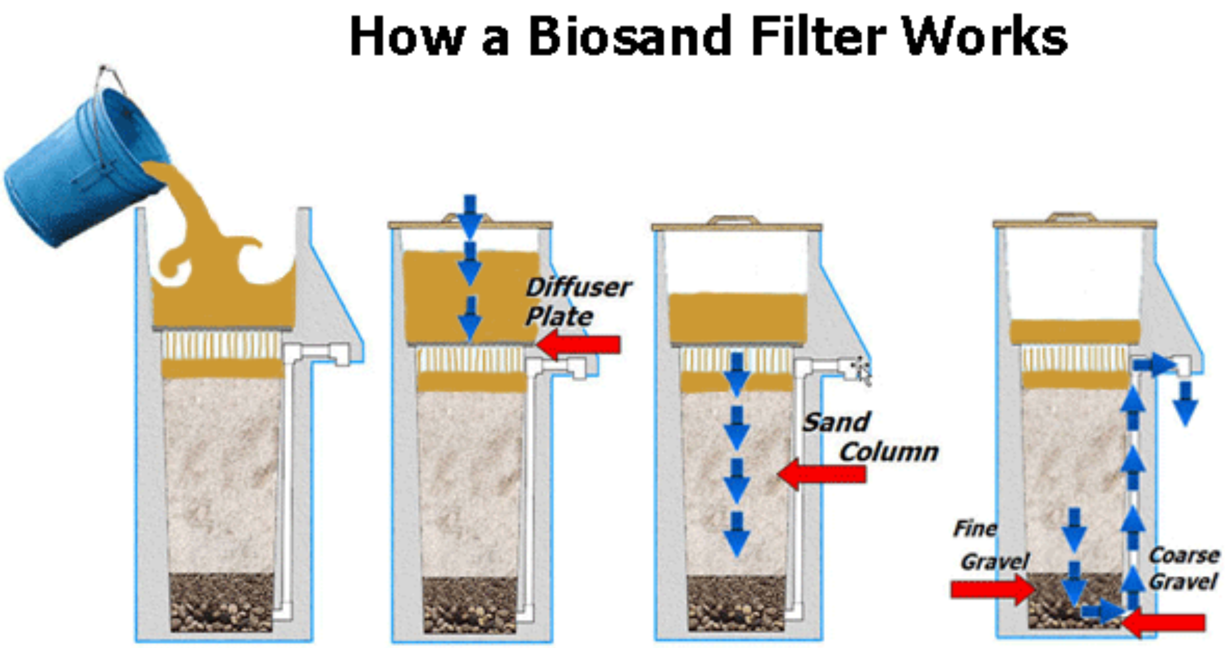
The crew is so proud to be rebuilding their community.

The HIDS Bio-Sand Water Filter

Concept

Two types of filters have been used in Haiti.

One has a single piece of cast concrete used as the structure
The other uses injection molded plastic from China as the structure.
Both use sand to establish an ecosystem that filters out most of the pathogens.   This is well established technology.



As a design challenge we decided to build the structure our of HIDS modular panels.

Advantages of HIDS Water Filters

Cost for Plastic system is $107 for plastic parts alone
Plastic body must be trucked to Duchity
Cost for HIDS structure is $25
We can make it in Duchity
Many homes are way beyond where any road goes.
The six concrete panels of the HIDS can be easily carried to location.
The construction in the community will provide jobs

Students build panels for water filter. Image shows all four stages. Wire alone in form. Single layer of concrete. Wire is getting concrete placed over it.   And in upper left, the finished panel.

The students placed the base on a bed of small gravel to level the structure.   The four sides are placed and wired together before being centered on the base and then attached to it.

The local bio-sand water filter technician Jolette Fortile, takes charge of the installation. This is what we had hoped for. Later she helped with the concrete work to attach the pieces. This was the first time I have seen a Haitian woman work cement.

Here is Jolette Fortile running the schools community based water program. She is responsible for keeping the cholera epidemic from spreading to this community.   The water filters and her hygiene instructions are working.

The UVM students in Senior Engineering Design discuss the next step in the installation.

After a period of developing a diverse biological layer that filters the biological pathogens from the clean water, the system is >99.9% effective against multi and single cell pathogens. They up to 98% effective against bacteria and even viruses.

For more information of bio-sand water filters and how they work, please visit http://www.biosandfilter.org/biosandfilter/index.php/item/297 and http://www.biosandfilter.org/biosandfilter/index.php/view/news/item/346

This site provides some data on pathogen filtering effectiveness.
http://biosandfilters.info/technical/fact-sheet-biosand-filter

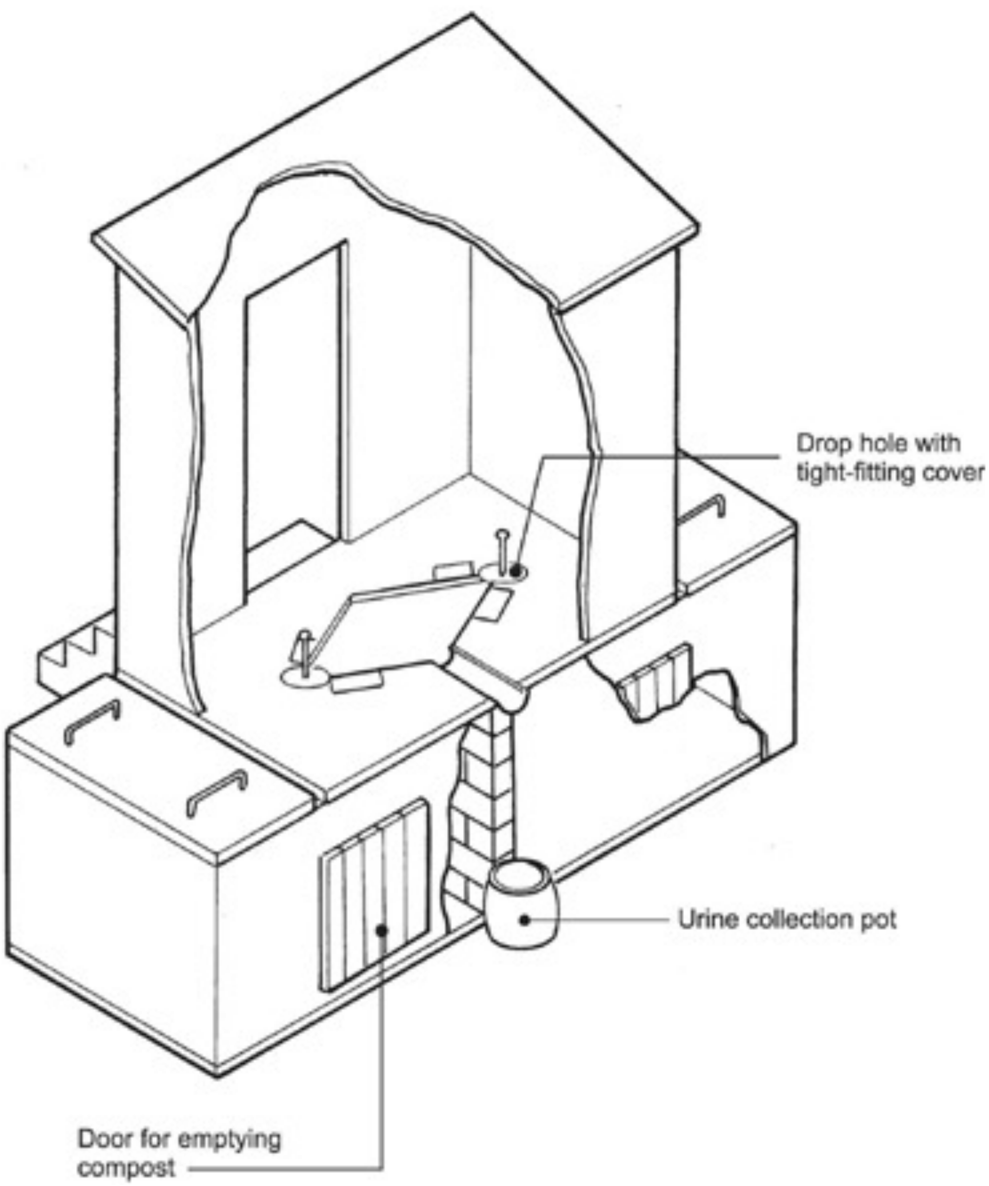
This shows the finished installation. The diffusion plate is made from a food grade bucket. Notice how beautifully the concrete was finished on the base. To make the system water proof a 6 mill black poly liner has been installed. We can install one of these for $60 including parts and labor, while the similar plastic filters by International Aid cost over $200 to install.

For cultural reasons we will need to paint the structure blue, and then it should be acceptable to the community.

The HIDS K.K.P. raised bed composting toilet

Most Haitians in the Duchity region have no access to any toilet facility. Some families have pit latrines. Most have never used a flush toilet.

There are several groups working to install one or two bin, composting toilets.



The above drawing shows generally how they work.   The problem is that they fill up, and then no one wants to dig out the human manure. I have seen three of them in Duchity and only one is fully operational. Most of them are built with no clean out door.

The manure when dug out is not fully composted due to lack of oxygen. It must be mixed and recomposed before it is free of pathogens and ready to use in the garden.

HIDS Design criteria

- Minimal or no moving of pathogenic human manure
- Use HIDS modular design
- Maximize nutrient recovery

We designed a system to do achieve these goals

UVM Senior Design Students install the first KKP raised bed. The Haitians are excited to get access to the system.

KKP stands for Human Manure Production in Creole.
The technology has been developed in the last 15 years to place nutrients from manure into a plant accessible form using activated charcoal. Ironically Haiti has a thriving cottage industry of making charcoal used for cooking. In the process of making, transporting and selling the "charbon" huge piles of waste charcoal develop. These are pieces too small to be of use in cooking fires. But they are fine for use in composting toilets to lock up the nutrients.

To minimize moving the pathogenic waste we place a portable outhouse on a raised bed built out of concrete panels.

The human manure goes straight into the raised bed. As it is filled biochar and soil are added to the bed to maintain roughly equal parts of each.

The activated charcoal locks up the nutrients in the manure and keeps down the odors.

After one month, or when the bed is filled up to 20 cm below the top, the outhouse is moved.

Above you can see the portable toilet placed on the raised bed panels. There is a pile of char ready to be placed on the human manure. Two poles attach to the outhouse brackets seen in upper right, to move it like a sedan chair

When the outhouse is moved a thin layer of char will be added on top of the waste mixture.

The next step is to place a solar cooker over the raised bed. Solar cooking technology has been used for many years. The goal is to raise the temperature of the human manure to at least 131°F (55°C) several times. This will kill any potential human pathogens.

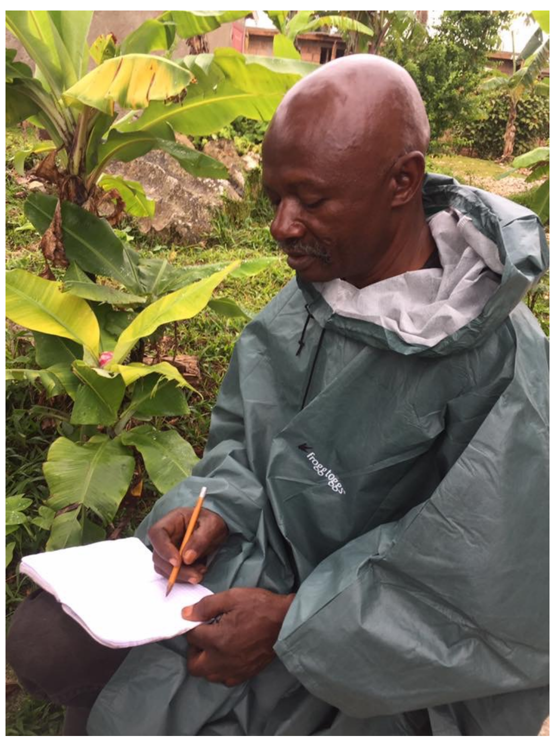
A double glazed system in Haiti with a small reflector to boost solar gain should be able to exceed 220 °F (104 °C) several days each month of the year. To ensure this a compost thermometer will be place in the soil to record the temperature at the bottom of the manure layer. the temperature will be recorded at noon each day and kept in a log. If it does not exceed 131°F on at least three days the solar cooker will be kept in place until it does.

When the soil is cooked, it will be planted. No root crops should be used. Only plants that have edible parts above the soil layer. Some mature compost from an older bed should be added to each plant so as to introduce bacteria and fungus necessary to maintain a soil ecosystem.

Up to three crop cycles can be harvested a year in Duchity.

In a 14 raised bed system, it will take 12 months of growing before the soil must be dug out and taken to the near by fields as fertilizer. The toilet is moved back onto the first raised bed and the system repeats.

This is my friend Felix Despagne as we talked about the KKP system He was seriously excited by its cost, ease of operation, and cultural acceptability. He wrote down all the component costs of the system. When the first plants grow to maturity, then everybody will be excited.



For information on how biochar reacts with nutrients such as nitrogen in waste see https://www.researchgate.net/profile/L_Van_Zwieten/publication/237079599_Agronomic_Values_of_Green_Waste_Biochar_as_a_Soil_Amendment/links/0c96052cb2c83cca11000000.pdf

For information on nutrients in human manure see http://ceadserv1.nku.edu/longa/haiti/kids/feces_value.html

Cost of KKP system	
Each raised bed, 4 panels at $6 each = $24	
$24 plus $6 labor per installation =	$ 30
14 raised beds x $30 =	$420
Lightweight portable outhouse	$250
Solar cover made with two sheets vinyl	$ 58
Cost to operate for one year	
Labor to move and clean outhouse system and provide char and soil	$72
Total cost of installation and operation for first year	$800

After the community learns how good this compost is for growing, the soil can be sold to pay for the operation.

The potential end state of the KKP system is to restore Haitian soil and fertility. If this takes off Haiti could once again feed its own population, and even export food.

Life cycle cost of environmental impact

Other groups are providing housing in Haiti. It is interesting that the cost per square meter is considerably higher than what we are building for. As to the environmental impact, to build with wood in very expensive. Furthermore, Haiti is becoming even more deforested and is already known as being the case point example of deforestation already. Thus many aid groups import wood into Haiti at great cost, or purchase the limited wood available from Haitian trees. To attempt to provide housing for low income Haitians with any other material than concrete makes no sense. The traditional housing with wood or concrete blocks is way to expensive and will not stand up to hurricanes.

Destruction in Duchity. The family is still living in the rubble of their home.

Destruction in one of the 20 outlying communities of Duchity.
Matthew ripped off the roof, and tore down concrete block walls.

Thus to accurately calculate the environmental impact of the HIDS technology, we need to look at the life cycle environmental cost of both systems.

If the HIDS Haitian Kitchen will last 70 years with some maintenance, and we compare it to a temporary house built from ply wood, 2x4 framing and a sheet metal roof, that will last less than 10 years, we need to multiply the environmental impact of the “temporary” house times seven.

We also need to look at the environmental impact of the KKP system. If the Haitian soil can be rebuilt, and a planting of fruit and nut trees is promoted, then the long term impact can be a return of carbon from the atmosphere into the redeveloping Haitian soil. This must be the long term goal. It has taken 500 years of exploitation of the Haitian people and environment to wreck such ecological devastation upon this country. The healing of the land must start, even if it takes hundreds of years to finish the job, one raised bed at a time.

Affordable housing from HIDS

Cost of a house for a year.
The Haitian Kitchen has a cost of $1,200
With minimal maintenance it should last for 100 years

Ignoring interest, this is a cost of $12 a year, or $1 a month

If a family of four lives in the structure, and the average per capita income in Duchity is $ 0.80 a day, this means a potential income of $3.20 a day, or $100.80 a month for the family.
Thus less than 1% of the average families income needs to go to housing.

The idea in this analysis is to show that this system is truly affordable by almost all Haitians.

Similarly, if we can install water filter for $60, and it services 10 people with potable water, The cost per person is $6. If the life of the system with minimal maintenance is 30 years, this costs $0.20 a year per person. This is 5/100 of a penny per day per person.

This is the end state we are working for.

Other ideas for the HIDS program that are in design phase only at this time.

Water Cisterns
Much larger domes
Barrel vaults structures
Erosion control systems and weirs
Paving stones for foot paths