Ti Kay Pay

A Straw Bale Rebuilding Solution for Haiti

Proposal

for the Government of Haiti's

Building Back Better Communities

Lot 1 : Housing Expo

Proposed by a Team of Building Professionals Expert in Strawbale Construction
and Other Appropriate and Sustainable Building Practices
Under the Auspices of Builders Without Borders

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Setting

The January 12, 2010 earthquake that devastated Haiti, causing the deaths of 230,000 and leaving 1.4 million homeless, was an enormous tragedy for the people of Haiti. But it also has yielded an enormous opportunity for Haiti to rebuild, restore, and revitalize itself in ways not possible before. In the building realm there is the opportunity, and truly the necessity, to rebuild in ways that are appropriate and sustainable culturally, economically, and environmentally. This Proposal for a Ti Kay Pay – a small straw house - is offered in complete alignment with those aims.

Introduction and Brief History of Strawbale Construction

Strawbale construction uses straw, compressed and tied into bales, as stackable blocks for wall systems. The stacked bales are usually covered with plaster - made from sand and a clay, lime, or cement binder, and often reinforced with fibers, mesh, or internal or external "pins" - to create a composite wall system.

Originating in the state of Nebraska in the 1890's, this construction method remained localized with sporadic use into the 1930's. Some of these early buildings are still in use. Rediscovered in the 1980s, and further investigated and developed, modern strawbale construction has been practiced for twenty five years, and is now found in 49 of the 50 United States, and in over 45 countries and in every climate across the globe, including in areas of high seismic risk, such as California, China, and Pakistan.

Simonton house, Nebraska (1908)

Community Center - Pakistan 2006

Hermitage – California, 1996

Residence – China, 1998

Strawbale construction has been used primarily for residences, buts also used for offices, schools, environmental centers, and retail stores. Strawbale buildings have ranged from the very small and simple, to the very large and elaborate. Although usually single story, two and even three story buildings have been constructed.

Why Strawbale Construction in Haiti?

Strawbale construction offers many significant advantages as a semi-urban and rural building system in Haiti.

- Low Cost: The estimated cost of materials and labor for the Ti Kay Pay shown in this proposal, with an interior dimension of 3m x 5m plus a front Galri, is between $1500 and $3000 USD. This is based on a four-year track record of 20 strawbale buildings constructed by the organization PAKSBAB (www.paksbab.org) in northern Pakistan, which has a similar wage scale and similar materials costs as Haiti. The two-room plus veranda 24'x24' PAKSBAB houses, with a similar construction system to the one in this proposal, have consistently cost approximately $2400 USD for materials plus 20% for labor ($2900 USD total). Using the unit cost of $5 USD / sq.ft ($53 USD / sq.m), yields the lower stated figure of $1500 USD. The higher figure of $3000 USD is conservative and adds 100% to allow for various unknowns, the inclusion of rainwater catchment and a small photovoltaic system, and because smaller buildings cost more per unit area (the Ti Kay Pay is roughly half the size of the PAKSBAB house). Note that in Pakistan the strawbale buildings cost about half of the same-sized reinforced concrete block buildings. A similar cost relationship is expected in Haiti between strawbale and confined masonry for example.

- Earthquake-resistant (see also Structural System): In laboratory tests, strawbale buildings have proven remarkably resistant to seismic forces. The most notable tests include:
  - 2002 – monotonic and reverse in-plane cyclic tests of 8' wall specimens at the University of Illinois. Test results available at www.ecobuildnetwork.org/what-we-do/straw-bale-test-program
  - 2004 - in-plane cyclic test of 4' wall specimen at California Polytechnic State University
  - 2009 – monotonic tests of 4' and 8' wall specimens, and a shake table test of full-scale house specimen of the PAKSBAB system at the University of Nevada. The house specimen withstood 1.4 times the ground force acceleration of the 2005 Kashmir earthquake. See the video of this successful test at http://nees.unr.edu/projects/straw_bale_house.html

PAKSBAB Shake Table Test - 2009

- Local Materials / Resource Efficient: Virtually all materials in the Ti Kay Pay are available in country, and most are available locally. The design minimizes use of materials that are scarce, expensive, environmentally harmful, or imported; such as wood, steel, and cement. The Ti Kay Pay utilizes a seasonally renewable agricultural waste product, rice straw, as the core of its composite wall system. Rice straw is plentiful in the Artibonite Valley and near Les Cayes. Annually renewable bamboo is used as external, wall-stiffening pins. The finish plaster consists of readily available clay (the binder), sand or other fine aggregate, and natural tensile fiber such as straw. The primary plaster reinforcing is either nylon fishing net, or a natural fiber mesh. The foundation system uses a rubble trench footing as well as crushed rubble, gravel, or earth in coursed geo-textile bags for the stem wall. The top plate of the wall uses wood, but shorter lengths can be spliced together, and bamboo is a possible non-wood option. The roof structure is shown as bamboo trusses, although options include "pallet trusses" made from wooden pallets or other short lengths of wood, or light gauge steel trusses.

Rice growing in Artibonite Valley

Straw bales fabricated in Pakistan

- Market for Straw, Job Creation: Substantial use of straw and straw bales as building materials, would create a market for rice straw (rarely utilized in Haiti, and worse, sometimes burned), and would create an industry for the manufacture of straw bales (currently unavailable in Haiti). As in Pakistan, bales can be made manually using a steel compression mold and farm jack. A first compression mold for this purpose has already been fabricated in Port-au-Prince.

- Culturally Appropriate Forms: Strawbale construction is easily adapted to architectural forms that are culturally appropriate in Haiti. The bales can be thought of as large, fuzzy, masonry units, that are stacked and plastered. The design form in this Proposal is that of the Ti Kay, the archetypical small rural cottage, but other rectilinear designs, and even curved forms are possible. The design shown allows for expansion to the rear with an extended gable roof, and to either side with shed roofs. Structurally, the design is single-story loadbearing, but two-storey buildings can be constructed with a post-and-beam structure and straw bale infill shear walls.

- Thermal Comfort: Plastered strawbale walls offer an optimal balance of thermal mass and thermal insulation. Although the tropical climate of Haiti requires little if any need for insulation against heat loss, the plaster on the walls provide sufficient mass to temper the day-night temperature swings, and the straw insulation helps keep the daytime exterior heat away from the interior. Also, a mixture of light straw-clay above the ceiling, provides an insulating barrier against radiant heat from the steel roof. Ample eave, ridge, and gable ventilation flushes the attic of hot air build up.

- Fire-resistant: Plastered strawbale walls are remarkably resistant to fire. In 2006, clay and cement plastered walls withstood 1-hour and 2-hour ASTM E-199-05a fire tests respectively. Test results available at www.ecobuildnetwork.org/what-we-do/straw-bale-test-program

- Acoustic Insulation: Strawbale walls are excellent acoustic insulators, offering acoustic privacy unmatched by conventional wall systems. This is especially advantageous in semi-urban locations, or if housing units are clustered or share walls.

About moisture: Ambient humidity, into the 80% range, is not itself enough to cause moisture related problems in strawbale walls (Haiti's highest daily average RH is 56%). However significant water intrusion without the ability to dry within a reasonable time-frame, can create rot or mold in strawbale walls. The building design in this proposal minimizes this risk by use of moderate roof overhangs and by keeping the bales well off the ground (.5m). Inherently, the clay plaster wall finish is hydrophyllic (readily absorbs moisture), thus helping keep any moisture that may reach the plaster/straw interface, away from the straw. Also, of all the cereal grains, rice straw (the type of straw available in Haiti) is the most resistant to decay. Strawbale buildings have been successfully in service for many years in tropical climates such as Hawaii, Nicaragua and Sri Lanka, and in regions of seasonal high rainfall such as the American northwest.

About insects: With minor exception, insects have not caused problems in strawbale buildings throughout the world. This includes termites, which have shown little or no interest in straw. Rice straw in particular, with its high silica content, is especially resistant to consumption by termites or other insects.

Structural System

The building type proposed is typically called a "strawbale building", but from an engineering perspective a plastered strawbale wall is a composite system in which the straw bales are only one component. The inner straw bale core, the outer stiff plaster with reinforcing, and wall ties all work together as a structural assembly. One that yields impressive results as a gravity load bearing and lateral load resisting system, all from simple and accessible materials such as earth, straw, twine, and wire. In engineering terms, a plastered strawbale wall functions as a stressed skin panel. It can be thought of as a "natural structural insulated panel" or a "natural SIP".

The proposed building uses its composite strawbale walls as both the gravity load bearing structure and the lateral earthquake and wind resisting structure. Seismic testing (see links on previous pages) has shown that the capacity, toughness (ductility), and energy absorption of strawbale walls can equal or exceed the capacity of wood framed plywood walls commonly utilized in high seismic regions of the United States.

The proposed design maintains a minimum of a 4 ft. (1.3m) shear panel at all four corners. This provides strong and balanced resistance to wind and seismic lateral loads. Under extremely high loads, even if the stiffer plaster skins degrade, the highly resilient straw bale core remains as a secondary load resisting and dissipating system. In all cases, the opposing and through-tied bamboo pins that capture both the stem wall and the top plate, provide excellent resistance to out-of-plane lateral loads. The top plate and the steel roof diaphragm complete the structural tie of the building at its top, with proper connections of all structural elements.

To address high wind forces from hurricanes, tensioned vertical strapping extends from the top plate to the underside of the gravel bag stem wall, and the roof structure is strapped to the top plate. The foundation stem wall extends .5m above the ground to help separate the straw bales from water at the ground and to provide significant mass low to the ground that stabilizes the wall and resists uplift from hurricanes or seismic overturning.

Although based on the successfully tested PAKSBAB system, there are differences in the Ti Kay Pay system which is tailored to circumstances in Haiti. Additional and more detailed analysis of the system is expected to occur. In all cases, the structural design will comply with the 2009 UBC and other codes identified in the RFP.

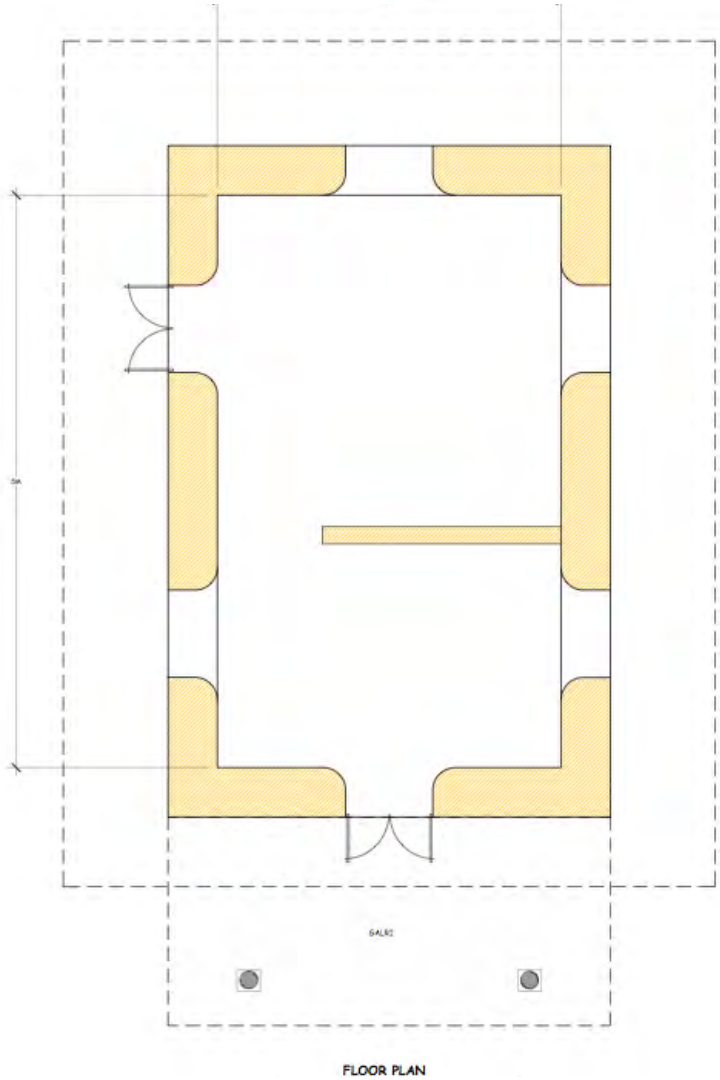
Associated Systems

- Electrical – Although not indicated on the Floor Plan, lights, switches and outlets would be included in the house, all powered by a modestly sized, 12V, direct current, photovoltaic system. The photovoltaic panel is indicated on the Right Side Elevation, but its location is dependent on the solar orientation of the building.
- Rainwater Catchment – The drawings show gutters and downspouts that direct rainwater to an above or below ground cistern.
- Sanitation – A small detached building, housing a composting or dehydrating toilet (such as those promoted by the organization SOIL) is suggested for a building of this small size. Such facility might be initially shared among households, and although important, is not currently included in this proposal. The safe use of human waste as an agricultural fertilizer is strongly encouraged. This has been practiced successfully in many regions of the world including Sweden, China, and parts of Africa.
- Cooking – A cooking facility is not currently integrated into the Ti Kay Pay. Cooking would generally occur immediately outside the home under cover of a roof overhang. Roofs could be extended or added to provide greater protection from rain or sun. A detached kitchen or a kitchen addition could be constructed by the owner. The use of 'rocket stoves' or other highly efficient stoves is strongly recommended.

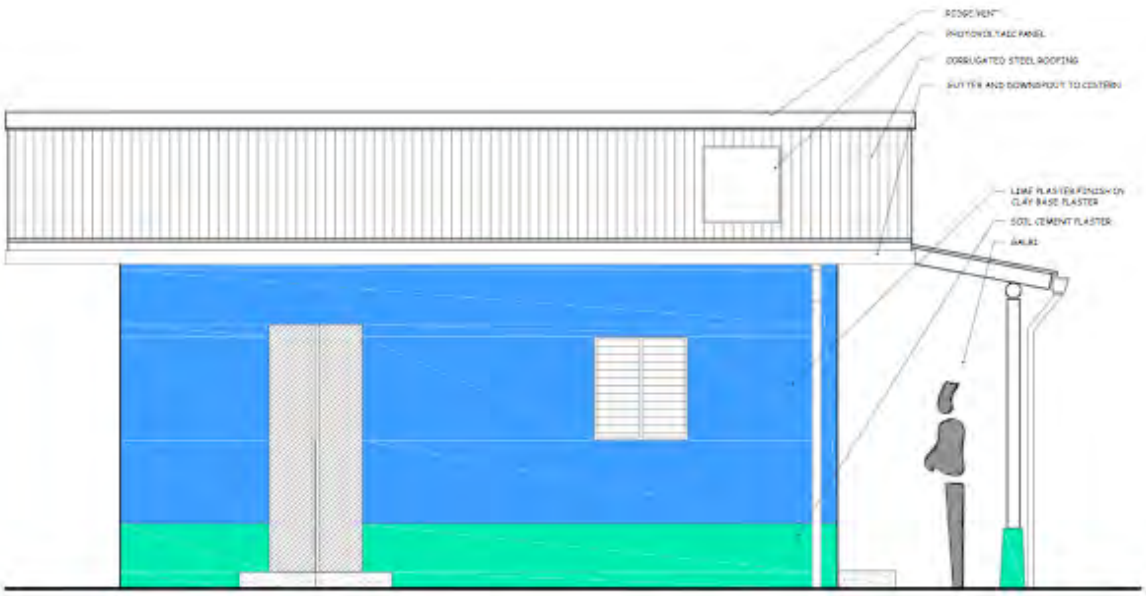
Photograph of Preliminary Prototype (under construction, Massachusetts, June, 2010)

Drawings of the Ti Kay Pay (Small Straw House)

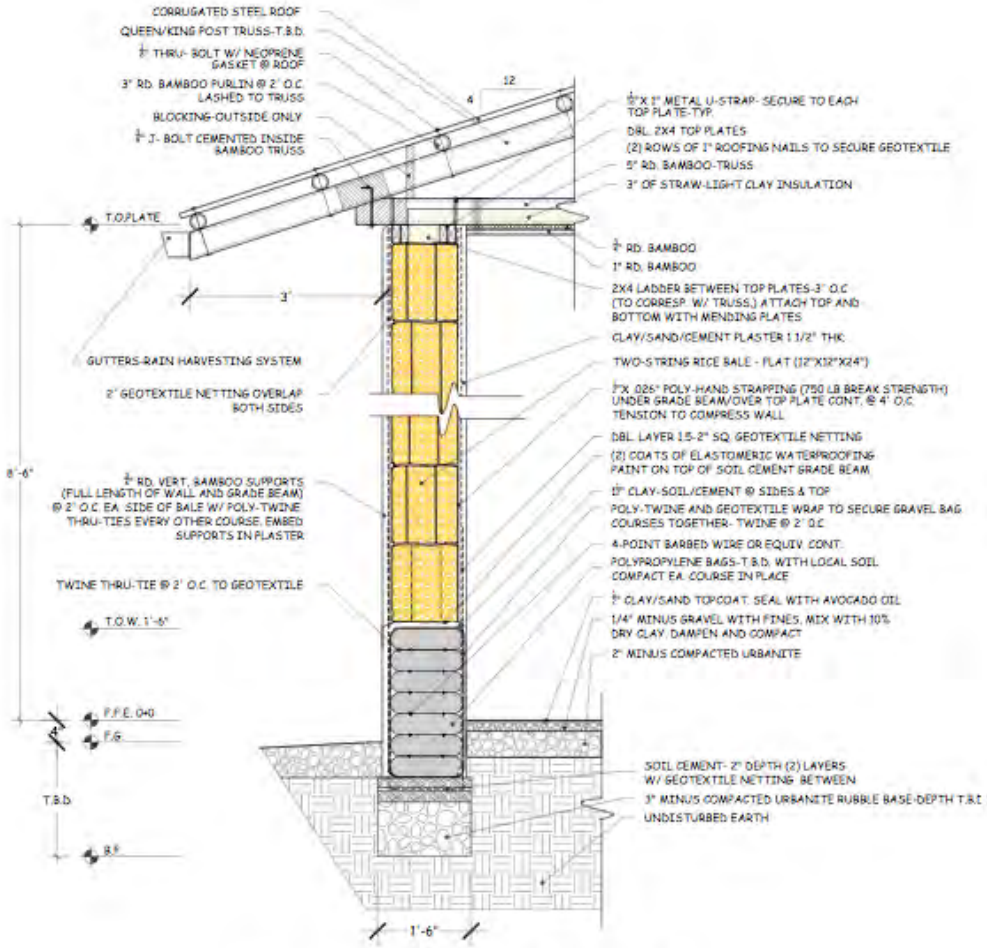
ELEVATION-FRONT



FLOOR PLAN



ELEVATION-LEFT SIDE



LOAD-BEARING WALL SECTION

Case Studies

Case Study 1 – Strawbale Housing in Pakistan

In 2006 and 2007 Martin Hammer helped found the organization Pakistan Strawbale and Appropriate Building (www.paksbab.org) with civil engineer Darcey Donovan, introducing strawbale and other appropriate building technologies to earthquake affected Pakistan. Strawbale construction is an earthquake-safe, resource efficient, culturally appropriate, and affordable alternative to the expensive, uninsulated reinforced concrete block buildings commonly being built in northern Pakistan, or the unreinforced stone buildings that performed so poorly in the 2005 earthquake. Twenty buildings have been constructed to date, and a specimen using the innovative fishing net reinforced strawbale building system underwent a highly successful shake table test at the University of Nevada in 2009. PAKSBAB continues its work, now comprised almost entirely of Pakistanis including its Director, and individuals continue to be trained with the construction of each building. This engagement with, and inclusion of the Pakistani people, and the frequent trainings conducted to facilitate technology transfer, would serve as a model for our strawbale construction efforts in Haiti.

Case Study 2 – Earthen and Bamboo Construction in Laos

In 2002 Kevin Rowell and Kleiwerks arrived in the Laotion village of Phoudindaeng, founded just five years earlier. Within two days he was asked by the village leader to work with the villagers, comprised of three distinct ethnic groups, to build a community center. In the first year a demonstration home was built and support had lined up to build the community center. At the ground breaking of the community center, the village leader commented, " We have planted a seed today in our community, with proper nurturing it will grow . . . . ." It has grown. With the completion of the community center, the villagers have a place to gather, to study, and hold festivals and meetings. The village has gone on to build a seed bank, a youth center and other projects in the area, using a combination of natural building techniques brought by the Kleiwerks team and the local traditional methods.

Case Study 3 – Presentation Center Dining Hall, California

Presentation Retreat Center is a conference center located near San Francisco. Its new Welcoming and Dining Facility is a strawbale building approximately 900 sq. meters in size. The center is in close proximity to the San Andreas Fault, a major fault in the State of California. The project illustrates the suitability of strawbale construction in assembly buildings in highly active seismic areas. In addition to the strawbale walls, the project implemented multiple sustainable features, including a living roof, passive solar, photovoltaic electricity, and solar hot water. Dan Smith of this Proposal team was project architect, and Henri Mannik of our team was a structural engineer for the building.

Point of Contact

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Team Profiles

Martin Hammer is an architect in Berkeley, California. He has designed over 160 residential, commercial, and institutional projects. Martin has been involved with the design, testing, engineering, and construction of straw bale buildings since 1995 and has experience with rammed earth, passive solar, photo-voltaics, rainwater catchment, greywater, and other sustainable building practices. He has been involved with the development of building codes for sustainable building materials and systems since 2001, including as author of a strawbale code for the State of California and the International Green Construction Code. He is a contributing author to the book "Design of Straw Bale Buildings", and is co-authoring a Strawbale Tutorial for seismically active regions of the developing world for the World Housing Encyclopedia. Mr. Hammer helped introduce strawbale construction to earthquake-affected Pakistan, as architect and project supervisor for the organization Pakistan Straw Bale and Appropriate Building (www.paksbab.org). In March and April Martin worked in Haiti as a member of reconnaissance teams from the Earthquake Engineering Research Institute and the World Monuments Fund. Martin is currently representing Builders Without Borders in Haiti working on many aspects of sustainable reconstruction.

Builders Without Borders (www.builderswithoutborders.org) is an international network of ecological designers and builders who advocate the use of straw, earth and other local, affordable materials in construction. Builders Without Borders believes the solution to homelessness is not merely housing, but individuals and communities trained to house themselves. To this end, Builders Without Borders organizes and promotes workshops and training events, creates educational books, manuals, and videos, and partners with other organizations to build affordable, sustainable housing. Since its inception in 1999, projects have been organized and supported in Mexico, Israel, South Africa, Siberia, Mongolia, Pakistan, and on Native American land. A BWB proposal was recently submitted to the U.S. Afghanistan Reconstruction Council (US-ARC) to train Afghan builders in the use of natural building materials. Builders Without Borders, is the umbrella organization for this Proposal, and is a project of Networks Productions, a 501(c)3 educational public non-profit organization.

Regine Laroche is an architect in Port-au-Prince. She has been in practice for 22 years with experience in Haïti and the US, with special interest in sustainable architecture and environmental education. She has worked in the public sector for the N.Y. Harlem Urban Development Corporation in community development and revitalization. Regine has worked in the private sector for Bryler Corporation and in her own practice, Atelier Laroche, working on residential, commercial and institutional projects. She has worked with multidisciplinary teams (planners, architects, sociologists, development, finance, and public health specialists) in health-related projects at local and national levels. Regine has provided technical assistance to grassroots and youth organizations in the context of environmental improvement and awareness programs (Wynne Farm Ecology Reserve, HUDC), and has participated in dialogue facilitation in troubled neighborhoods in Port-au-Prince (Concern Worldwide, Peace-Building Program).

Henri Mannik is a structural engineer in Oakland, CA, with particular interest in the integration of architecture and structures. His structural work includes buildings in the high seismic areas in and around San Francisco. His experience ranges from advanced seismic design of conventional steel, wood, and concrete structures to innovative and sustainable structural systems such as strawbale construction.

Current projects include a masonry residence on the California coast designed using Performance Based Seismic Design which seeks a specific controlled and minimal level of earthquake damage which is beyond the basic code requirement of life safety. His engineering practice also includes a building on the Hawaiian island of Kauai designed to minimize hurricane damage. Past work includes residential strawbale buildings and two strawbale assembly hall projects. The dining hall of the Sisters of Presentation Retreat Center, which is in close proximity to the San Andreas fault, and Oak Lodge in the Sierra Nevada mountains in California. This project includes structural strawbale walls which are its wind and earthquake resisting elements.

Andy Mueller is principal of GreenSpace Collaborative (www.greenspacecollaborative.com), a natural design and build company founded in 1996 in Massachusetts. He has a background in design and project management in architecture and landscape architecture. Mueller earned a Masters of Landscape Architecture and a Bachelor of Environmental Design and Art from the University of Massachusetts. He studied Green Planning and Architecture at the Universitat Hannover in Germany. He has extensive hands-on experience in landscape design and natural home building with an emphasis on small footprint structures. Mueller is dedicated to developing projects to better utilize his skills for the benefit of those less privileged or in greater need.

Andy is a board member at The Sheltering Pine Institute, a non-profit organization dedicated to building just, vibrant, and sustainable human ecosystems. He is also Co-founder of Natural Builders Northeast (www.nbne.org), a network of builders, designers, consultants, educators, and professionals practicing the art of natural building and design. In March of 2010 Andy toured Haiti and established contacts in several rural communities researching the availability of local materials for a straw bale house prototype.

Kevin Rowell is founder and owner of The Natural Builders (www.thenaturalbuilders.com) a design and contracting company in the San Francisco area, specializing in natural materials and building systems, including strawbale, cob, straw-clay, and bamboo. Kevin is Program Director for Kleiwerks International (www.kleiwerks.org), which has helped train thousands of people in the construction of shelter with local materials in Laos, Thailand, Cambodia, USA, India, Mexico, Peru, Argentina and Costa Rica. Kevin and Kleiwerks have been in Haiti since February, working and communicating with numerous NGOs and government officials. Kevin has recently established the Co-Laboratory in association with UN-Habitat, and the Haiti National Testing Laboratory, to test appropriate and sustainable building materials and systems for use in Haiti's reconstruction.

Dan Smith is an architect and principal of DSA Architects in Berkeley, CA, an award-winning innovative design firm focused on sustainable, affordable, energy efficient alternative building systems, including net-zero energy buildings. DSA has designed over 40 strawbale building projects, including prototype strawbale buildings in Mongolia and Ireland. In 2003 Dan was part of the California seismic strawbale testing program of the Ecological Building Network. Dan has advised PAKSBAB in developing their seismic details for their strawbale wall system in

Pakistan. DSA was a main designer of the Global Homes system, an innovative, low Portland cement block system for self-help construction in developing countries such as India and Africa. Dan has recently worked with Architecture For Humanity on the development of an alternative masonry unit, with particular application in seismically active developing countries such as Haiti.

Team Commitment to Delivery Dates and Involvement of the Haitian Community:
If this Proposal is accepted, our team is committed to meeting the delivery dates listed in the RFP. Team member Regine Laroche is a permanent resident of Port-au-Prince and would act as primary Haitian consultant. Kevin Rowell is indefinitely a resident of Port-au-Prince, and would act as primary technical and logistics advisor. Martin Hammer would return to Port-au-Prince in the role of project supervisor, and Andy Mueller would return in the role of project foreman. Henri Mannik and Dan Smith would provide remote technical support as needed.

The four team members in Haiti would bring additional Haitians into the team, and would conduct a training program with and for Haitians during the construction of the prototype. Note that because there is no native Haitian strawbale construction expertise, this method of construction requires that the team be initially comprised mostly of non-Haitians who do have expertise. However, it is our full intention to both continue learning from Haitians, Haitian culture, and the Haitian environment as the project evolves, and to directly involve Haitians at every level, and ultimately give this adapted strawbale construction technology to the Haitian people for their continued use.

Transportation, Installation, Logistics, and Production:
There are no unusual transportation or installation requirements to construct this building type, as most of the materials are local or readily available in country. The straw for the bales can either be brought in loose and baled on site, or baled at the source, and then trucked to the site. If there is demand for significant numbers of housing units in the first year following the Expo, our team will increase training, and bring in new team members as required to meet the demand. This would especially include previous trainees who were particularly diligent and skillful.

Access:
Our team recognizes the particularly high incidence of physical disabilities that now exist in the population as a result of the earthquake. Our Ti Kay Pay design is very simple, is on grade and is barrier free.