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ORIGINAL RESEARCH PAPER

The Haitian housing dilemma: can sustainability and hazard-resilience be achieved?

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Abstract The present danger in the Haitian rebuilding efforts, outside of the extreme level of need that often encourages temporary solutions at the expense of long-term capacity building, centers on the assumption that sustainability and resilience are mutually exclusive. They cannot be if this rare opportunity to achieve meaningful long-term change within a country that has suffered for far too long is to be fully seized. This change can be realized only with appropriate policies and incentives that do not simply fund the re-implementation of vulnerable construction modes in an effort to meet immediate needs, but that foster the introduction of alternative structural systems with the requirement that they build genuine local capacity to deliver sustainable and resilient homes that meet Haiti's cultural and economic constraints. This short communication reviews the important housing dilemma Haiti now faces, a dilemma with international extensions since researchers and construction firms from all over the world (including France, Germany, Italy, Greece, Japan, Canada, US) are involved, and presents thoughts for the importance of offering solutions that serve both ends of the economic spectrum, are hazard-resilient and truly sustainable.

Keywords Haiti · Rebuilding · Hazard-resilience · Sustainability

1 Introduction

Tens of thousands of Haitians in urban zones lost their lives in the January 2010 earthquake (Eberhard et al. 2010) in the one place where families should feel most secure—their homes. Close to 2 years after the earthquake, the majority of these displaced families are still waiting in tent cities for permanent housing they can call "home" in conditions worsened by heavy

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seasonal rains, hurricanes, and the Cholera outbreaks of late 2010 (Farmer 2011) and are now facing forced evictions without any roadmap toward permanent home ownership (Phillips 2011). Unfortunately their plight creates a considerable risk for well-intentioned aid and recovery to actually pose greater harm than good, similar to the trends observed in Africa, as the pressure to meet immediate human needs often leads to imported resources and infrastructure that cannot be sustained after non-governmental organizations (NGOs) withdraw their aid (Moyo 2009). Therefore it becomes essential that the effort to meet basic human needs in the short term is flanked by the implementation of infrastructure, institutions and policies that can build the capacity of the Haitians in the long term. While many agree that sustainable redevelopment and self-reliance is essential for Haiti, few appreciate how it can be practically achieved, particularly in the domain of urban residential redevelopment. In a year's time, the authors made three reconnaissance trips to Haiti (Mix et al. 2011) [http://haiti.ce.nd.edu] and are focused on development of a long-term sustainable plan for residential housing for low-income Haitian families, focusing on the rebuilding process for the city of Léogâne, where their University has had a strong presence for a few decades.

It is first important to note some unique attributes of the structural systems employed for urban housing in Haiti. Historically, due to the lack of wood, for use either as formwork or as a partitioning alternative, and the high cost of steel, cement and quality aggregate, Haitians employed construction with heavy masonry walls made of hand pressed concrete masonry units (CMUs) and lightly reinforced, undersized concrete columns, made with inferior raw materials and having inadequate strength and ductility. This combination, along with the lack of beams that would better engage the columns against earthquake loads, created systems that actually performed well under strong winds common to the Caribbean, but were conversely proven to be extremely vulnerable to earthquakes, failing through brittle collapse modes, as documented in the authors' personal reconnaissance database through their field work in Haiti [http://haiti.ce.nd.edu]. Furthermore, as discussed in more detail in (Mix et al. 2011), these construction practices in Haiti, which had no prior consideration of seismic threats, could be erroneously interpreted as confined masonry, but actually are driven by the scarcity of wood for formwork, such that CMU walls are erected first and scrap wood is then attached to the walls so columns can be cast. Bearing this in mind, the authors identified several recurring failure mechanisms in this system based on their field reconnaissance in Léogâne (Mix et al. 2011):

- Shear Failures: Rigid (exterior and interior) walls constructed with lower quality CMUs that are sufficiently stiff to attract seismic forces but with insufficient strength to resist them, transferring significant shear forces to adjacent columns upon failure.
- Flexible Diaphragms and Punching Shear Failures: Flat slabs (serving as both floors and roofs) lacked sufficient diaphragm action to engage columns and form an effective lateral system in homes with elongated floor plans, lack of beams, and inappropriately reinforced column/plate connections.

Contributing factors to the above failure mechanisms:

- Columns not sized for strength but for constructability (match depth of CMU walls implemented first in construction sequence), inadequately detailed/confined due to complete lack of design/construction provisions and high cost of steel (high import taxes).
- Excessive Mass: reinforced concrete floor/roof systems, CMU used for all partitions.
- Poor materials (concrete mixed from smooth river rock, beach sands), often separation of large aggregates from the mix in casting and weak CMU blocks used for masonry walls.
- Incremental construction, with houses constructed over an extended period of time, causing significant variation in material quality and workmanship.

This short communication reviews the important housing dilemma Haiti now faces and advocates for solutions that are both hazard-resilient, addressing these fundamental shortcomings, and truly sustainable, based on locally available material and expertise. It should be stressed that this topic has great international extensions since researchers, construction firms, aid organizations and policy makers from all over the world (including France, Germany, Italy, Greece, Japan, Canada, US) have combined efforts in search of potential solutions.

2 Sustainable and resilient rebuilding

The current absence of truly sustainable solutions to urban housing in Haiti is no surprise. This can be attributed in part to the fact that existing options used in other seismically active regions and even other parts of the developing world cannot be extrapolated to this application due to Haiti's unique requirements and constraints on housing. As the poorest Western nation with the highest import taxes and severe deforestation (Farmer 2011), sustainable construction practices cannot rely on the many engineered materials that are required in traditional code-compliant designs. The challenge of this engineering environment is heightened with the need to now insure resilience to both hurricanes and earthquakes, while still supporting cultural preferences towards privacy and security that lead to highly partitioned homes (Mix et al. 2011). Unfortunately, the ability to build the Haitian capacity for sustainable and resilient infrastructure is further hampered by the pre-existing lack of education, codification and oversight to regulate its construction processes. The fact that their entire concept of hazard resistance was focused solely on hurricanes (since the latest seismic excitation that significantly affected this region dates to the previous century) and the structural systems therefore employed lacked any aseismic considerations, adds to the complexity of the problem. These factors provide an important context to understanding the causes for the widespread destruction after the earthquake, but sadly create what may be the most difficult reconstruction effort following any major disaster.

After similar catastrophic events (Youd et al. 2000; Jain et al. 2002; Urzarski and Arnold 2001), the common engineering approach has been to tweak existing construction practices and design code provisions, based on the observed vulnerabilities, to provide better resilience against natural hazards. This process, applied time and again in countries like the US, Turkey, Taiwan, China, Italy, Japan and more recently Chile, by default is "sustainable," as it is based on established expertise, materials and systems already proven viable in the affected region. However, the complete absence of government oversight for construction and the very unique societal constraints of Haiti provide immense challenges and preclude this customary approach of simply refining or expanding the pre-existing body of knowledge. One could argue that the simplest remedy would be to simply implement recommendations that are direct extensions of current practices, for example, formally introduce confined masonry construction to Haiti. The authors, as part of the Rebuild Léogâne Community Planning Workshop that advocated for community-driven solutions in a participatory context, evaluated dozens of potential structural systems, partitioning systems and roof/floor systems across twelve dimensions that included constructability, long-term sustainability, functionality and hazard resilience (Rebuild Léogâne 2011). Indeed given the severely limited availability of local construction-grade materials and the functional requirements of Haitian urban housing, confined masonry surfaces as the most immediately implementable solution. As such it has received the most attention from groups like Confined Masonry Network (http://www.confinedmasonry.org), MCEER (http://mceer.buffalo.edu/education/UniQ/) and Build Change (http://www.buildchange.org/haiti.html), whose education and outreach programming are focused on

proper aseismic implementation of these and other reinforced concrete systems familiar to Haitian builders. For organizations like Build Change, "minor, low-, or no-cost improvements to existing ways of building" often proves easier "than to introduce a completely new technology or reintroduce a traditional building method" (Hausler 2010). Unfortunately, engineering adequate seismic resilience of these "existing ways of building" through higher quality CMU and larger quantities of steel can cost up to $20,000—well beyond the reach of the majority of displaced Haitians who have no source of income (Phillips 2011). So while this is a solution for some, it is not the solution for all and though some would advocate for substantial subsidies by foreign entities, this poses the legitimate danger of creating perpetual dependence on foreign aid for even the most basic infrastructure needs (Moyo 2009).

Since earthquake-resistant construction is prevalent throughout the developing world and, when properly designed, can be resilient to earthquakes, the challenges facing Haiti are often dismissed under the assumption that a similar level of resilience could be achieved in this context by simply "importing" and enforcing US or International Building Codes and established systems like confined masonry. It is first important to distinguish between critical public infrastructure and residential housing. Certainly critical infrastructure like schools and hospitals can be designed to meet accepted codes and standards using internationally conventional design and construction approaches, since historically their development in Haiti has been largely supervised and facilitated by the financial support of NGOs. However, there is a fundamental flaw in assuming a similar level of support can or should be extended to residential housing, even in short-term rebuilding, as homes never have and never will be financed to this degree in Haiti (Kidder 2003). The lack of locally-available construction materials, including the wood necessary for formwork to cast earthquake-resilient concrete frames, the steel necessary to provide strength and robust ductile behavior, or the quality masonry for confined or load bearing masonry construction makes the expense of this style of construction too great to serve the needs of the majority of displaced Haitians living in extreme poverty.

It is this lack of understanding surrounding the requirements for Haitian homes and the locally available construction technologies, materials, and practices, as well as the vulnerabilities they create, that leads to the speculation that "…building code [adoption] and [strict enforcement]" is THE solution to the Haitian urban housing dilemma (Lindell 2010). This then leads to well-intentioned efforts to educate masons, architects and engineers to facilitate Haitian-led masonry reconstruction, which certainly is sustainable as it uses local materials and native construction technologies, but due to the lack of resources can lead, in the long run (in absence of donor funds provided by foreign aid), to the re-employment of the same building systems that proved deadly in the 2010 earthquake. Solely encouraging the continued use of masonry-based structural systems by providing education and one-time access to high quality construction materials through relief funds, suggests to Haitian builders that such housing designs can be made truly resilient (as demonstrated in the example in Fig. 1) and that simply is not accurate, especially if one considers the materials available to the typical Haitian family in the absence of foreign aid. This is nothing short of false hope, particularly since updated assessments of the seismic hazard suggest that there is substantial earthquake risk throughout Haiti, with locations such as Port-au-Prince and the Enriquillo Valley (the epicenter of recent seismic activity) demonstrating increased vulnerability due to potential site amplification phenomena (Frankel et al. 2010). As these revised seismic hazard forecasts are significantly greater than previous estimates (Shedlock 1999), permanent housing introduced in the coming years must present solutions that span the resource spectrum available to Haitians. In other words, to avoid repeating this tragedy in the next earthquake, the poorest of Haitian families need to be presented with alternate affordable housing models with new structural systems and materials.

Fig. 1 *Left* pancake collapse of home in Léogâne, Haiti, instigated by insufficient columns and heavy partitioning (documented in March 2010). *Right* reconstruction of same house in August 2010, following re-education of head mason, yet design still based on same principles that created original vulnerabilities. Note that though the construction sequence is similar to that for confined masonry, the insufficient strength of the CMU blocks and the lack of provisions for appropriate connection to the reinforced concrete elements will ultimately prevent the structure to behave as such (nor was the intention of the head mason to establish such behavior)

So how then can options for sustainable, affordable and safe permanent housing be generated? It begins with the Interim Haiti Recovery Commission, who has set forth a comprehensive Action Plan for this nation. The plan encompasses issues associated with economic, social and institutional rebuilding as well as territorial rebuilding, which specifically addresses reconstruction of affected regions where over 100,000 homes were destroyed and more than twice that were damaged (Government of the Republic of Haiti 2010). While these statistics reiterate the colossal nature of the rebuilding effort ahead, the Plan can offer few specifics as to how this recovery will unfold, though one observation of the Commission is quite telling: "The reconstruction cycle for public buildings is well known and in this case, the building standards and zoning regulations should be quite simple to apply. It will be a different matter for the reconstruction of the private sector" (Government of the Republic of Haiti 2010). In this regard it will be critical for the Commission to strike a delicate balance between the desire to meet their five year objective of 100,000 new homes, while still insuring that these residential designs are both resilient and sustainable. In fact, the goal of 100,000 homes in 5 years is in itself quite ambitious, since over a year after the earthquake, the distribution of even temporary shelters had been hindered by the legalities of land ownership rights, creating significant frustration among the 4,700 households of Internally Displaced Persons (IDPs) in Léogâne alone (https://sites.google.com/site/shelterhaiti2010/). In fact, few NGOs have even focused on permanent housing, particularly within urban zones, e.g., groups such as Architects for Humanity and Spanish Red Cross have only been successful in delivering semi-permanent housing in the surrounding rural areas of Léogâne. Moreover, the authors' interviews with IDPs in Léogâne and those by other organizations in camps throughout Port-au-Prince (Phillips 2011) confirmed that the vast majority remain without a pathway toward homeownership. Even the more affluent homeowners who have begun reconstruction are doing so with systems that very much mimic pre-quake designs with modest increases in reinforcement and are reluctant to cast concrete floors/roof slabs, acknowledging their continued mistrust of traditional systems, leaving most homes as nothing more than an incomplete collection of CMU walls. Clearly, the solutions to the complex problem of urban housing in Haiti are not immediately evident, but it is certain that they will require far more than "develop[ing] the professional construction sector with laws and regulations relating to earthquake-resistant and hurricane-resistant materials and implementation" (Government of the Republic of Haiti 2010) or providing one-time

IDP relocation payouts of $250 that are inadequate to construct even the most crude of shelters (Phillips 2011).

Unfortunately the calls for a "comprehensive assistance program to ensure that displaced families have access to durable and sustainable housing solutions" (Phillips 2011) will not be answered unless the institutions overseeing construction promote the identification of alternative housing systems that can be eventually sustained without foreign subsidies and articulate clear policies that mandate that permanent housing designs demonstrate legitimate sustainability as well as dual hazard resilience. Sadly efforts to date have been unsuccessful when one considers the alternative housing models presented thus far at venues like the Building Back Better Communities Expo, sponsored by the Clinton Foundation. Not only did a number of designs fail to meet basic engineering requirements, but many of the housing models retailed for $20,000–$30,000, and only an estimated 10% relied exclusively on local materials (Macdonald 2011). Without impetus to propose more thoughtful solutions, time and money will continue to be wasted in such venues while IDPs remain in substandard conditions perpetuated by forced evacuations (Phillips 2011). Unfortunately, policy and regulations to incentivize responsible or innovative practices often focus on *public* infrastructure, but in this disaster it was *private* infrastructure that caused the vast majority of deaths and injuries and is the least equipped to sustainably recover given the economic climate and the lack of education and oversight pre-dating the earthquake. Therefore, without a thoughtful policy mandating that housing options, like the ones presented at venues like the Building Back Better Communities Expo and ultimately receiving contracts as part of the aggressive rebuilding plans being proposed by Haitian President Martelly (Phillips 2011), meet key criteria for hazard resilience and sustainability (in absence of donor funds), the largest vulnerability in Haitian infrastructure will remain unaddressed.

3 Closing thoughts

While this short communication reflects on the authors' experiences in Léogâne, the approximate epicenter of the January 2010 earthquake, they sadly are but a microcosm for other parts of Haiti that were similarly impacted. It is currently estimated that 595,000 Haitians are still living in approximately 900 IDP camps in and around Port-au-Prince (Phillips 2011). While the official number of people living in such camps has declined, recent surveys have found that 34% of displaced persons reported leaving their camps because they were forced out by evictions and have been unable to find sustainable housing, forcing them into even worse living conditions (International Organization for Migration 2011). While the majority of these individuals (76%) have expressed that their primary concern is housing/relocation, a clear path to homeownership that does not rely on donor funds has not been offered to them (Phillips 2011) and quite frankly has not received legitimate attention thus far. Most efforts have focused on providing solutions that could immediately support short-term housing needs, including providing one-time cash payments that desperate families often must spend on other needs, leaving them completely reliant on foreign aid. Yet out of this tragedy, Haiti's very rare opportunity to achieve meaningful long-term change (Farmer 2011) can be seized but only with appropriate policies and incentives that do not simply fund the re-implementation of vulnerable construction modes or heavily subsidized engineered designs well beyond the financial reach of most families.

Moreover, sustainable and resilient recovery in Haiti will not only benefit its people, but can provide hope for the one in seven around the world presented with similar silent risks. For the first time in human history, the majority of the world's population has shifted to urban

zones, leading to the formation of "mega-cities" with high concentrations of population subject to tremendous risk. As the majority of these emerging mega-cites are in developing countries, often typified by unstructured settlements and non-engineered construction, their risk is driven by extreme vulnerability (Munich Re Group 2004). As Haiti has taught us, vulnerability stems from two potential sources: (1) lack of knowledge and (2) lack of resources to implement this knowledge properly. Indeed the first must be addressed to build the necessary local capacity in the long term and has been the focus of most NGOs focused on education and outreach; however, even when the threat of a seismic hazard is well understood (Kerr 2010), all the education, building codes and enforcement in the world cannot eliminate the risk it presents if builders have only failed housing designs at their disposal or when extreme poverty creates the inability to safely implement any improvements on these designs. The only remedy is to flank these efforts with policies that encourage and support research to develop alternative, low-cost, sustainable housing that provides hazard resilience, while operating within the economic and cultural constraints of these regions so that all families will have a legitimate pathway to empowerment.

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