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RESILIENCE IN DESIGN AND CONSTRUCTION: HOUSING AND SCHOOLS IN BANDA ACEH

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Abstract

Post-disaster recovery and community resilience depend on several factors, including the community's population and demographics, natural environment, governmental services, physical infrastructure, lifestyle and community competence, economic development, and social cultural capital [1]. While each of these interdependent factors affects recovery and resilience, the physical infrastructure is often the most visible harbinger. People expect to rebuild or repair their homes and to resume ready access to their schools in order to experience a sense of normalcy.

This research focuses on observational and photographic data collected in 2019 of houses and schools in Banda Aceh that were designed and built after the 2004 Indian Ocean earthquake and tsunami. Additional data were collected through interviews with homeowners, school administrators, and local building and construction officials. At the time of their design and construction, the houses were promoted as being the best in terms of sustainability and the schools were described as being both seismically safe and sufficiently sound to last 50 years. One goal of the research was to assess how the choices for design and materials fared in the intervening years.

Several aspects of school design and construction were observed, including the mix of concrete used, the material used for window frames, whether air vents were placed to minimize problems with moisture, and whether stairwells were constructed and maintained properly.

With respect to housing, the research looked at the use of confined masonry, the mix of concrete used, whether gable walls made of timber lasted and if not, whether they were replaced and with what, and whether roofing proved durable or was damaged and later replaced. Interviews with homeowners revealed what they liked best about their reconstructed homes including whether they viewed them as sufficiently large.

In addition to observing reconstructed schools and homes, individuals were asked if they knew what to do in the event of another disaster and how they thought their community might respond to and recover from one. These questions offer insight into other important aspects of a community's resilience such as its social cultural capital.

Overall, this empirical research represents a unique study with its focus on a community in a developing country that endured significant destruction and that was reconstructed using methods intended to enhance the sustainability and seismic safety of the built environment and therefore its resilience.

Keywords: community resilience; schools; housing; design; construction

1. Introduction

This paper shares the results of a walking survey of villages near Banda Aceh, the capital and largest city in the province of Aceh on the island of Sumatra in Indonesia, 15 years after the 2004 Sumatra-Andaman Islands earthquake. The 2004 earthquake, which occurred at 00:58:53 UTC on 26 December, was an undersea megathrust earthquake that registered a magnitude of 9.1–9.3 Mw. Its cause was a rupture along the interface between the Burma microplate and the India Plate. The earthquake's epicenter was 255 km from Banda Aceh, off the west coast of northern Sumatra. It was the third largest earthquake in the world since 1900 and the largest since the 1964 Prince William Sound, Alaska, earthquake [2]. The earthquake was felt in Bangladesh, India, Malaysia, Myanmar, Thailand, Sri Lanka and the Maldives [3]. A series of tsunami waves heading inland grew up to 30 meters (100 ft) high. Coastal communities alongside the Indian Ocean were devastated by the tsunami, which reportedly killed at least 108,100 people and left another 127,700

missing in Indonesia. Banda Aceh and its surrounding villages had the largest number of victims [4]. Overall, the earthquake and tsunami were responsible for 283,100 deaths in 10 countries in South Asia and East Africa [5]. Despite the staggering statistics associated with the 2004 earthquake and tsunami, some good has occurred in their aftermath. For example, since 2004 there has been a general cessation of the conflict that had characterized the city of Banda Aceh and its province [4]. Likewise, domestic and international aid have enabled major modernization efforts and reconstruction of the city, one-third of which was destroyed by the tsunami [4].

The research described in this paper was conducted in September 2019. Operating within an overarching framework of resilience reconnaissance [6], this research takes a longitudinal approach and explores how well a representative sampling of housing and school structures built in smaller villages in the aftermath of the earthquake and tsunami have continued to perform over the past 15 years. It also explores occupants' perceptions of these built structures and their ability to serve their intended functions, including their ability to maintain the safety of occupants. Finally, it explores occupant perceptions of their community's recovery to date and community members' likely response to another large-scale earthquake and tsunami.

2. Background: The Disaster Life Cycle and Reconnaissance

The four phases of the disaster life cycle include mitigation, preparedness, response, and recovery. In terms of mitigation, Mitigation includes efforts to reduce the potential impact of a disaster, such as elevating homes located in a flood plain or declaring such locations unacceptable for building. Preparedness includes activities that enable effective response to an event, such as training government officials, emergency responders, and community residents as to the actions they should take in the event of a disaster. Response includes actions taken during or immediately after an event, including search and rescue, provision of medical care, evacuation, and attempts to reduce further damage to the built and natural environments. It is when people are expected to act on their preparedness training. It is often the phase most likely to attract mass media attention [8]. Recovery is the last phase. It depends on what has happened in the prior three phases, and involves all actions intended to return the community to its pre-event "state or better – and ideally to make it less vulnerable to future risk" (para. 5) [9]. While many people want their community to return to its pre-disaster state as soon as possible, "Due consideration must be given to when, where, and how to rebuild, mindful of not reproducing the unsafe conditions that may have existed before the disaster" (p. 313) [7]. This aspiration, while laudable, may prove impossible to achieve for reasons of community will, resource availability, land-use restrictions, and economic considerations. Community recovery in the aftermath of disaster is not an assured outcome; many factors influence its likelihood and degree, including the community's pre- and post-disaster demographics and its political/governmental, economic, social, and cultural health [10]. Each of these factors, considered in the context of the community's natural and built environment, affects the community's resilience or ability to rebound from the disaster [1].

Traditional earthquake reconnaissance typically occurs when the community is segueing between the response and recovery phases. Teams of technical experts – historically, engineers and architects specializing in structures, geotechnical, and lifeline issues – conduct "general damage surveys of a region or area following an earthquake to document initial important observations about earthquake impacts" (p. 1) [6]. Often, experts in other disciplines, such as sociologists, urban planners, political scientists, business professors, and others, will join these technical experts in their investigations. Decades of earthquake reconnaissance around the world have yielded significant learning about the impact of earthquakes on the built and natural environments; changes to building codes, design, and construction have benefitted from this learning. More recently, interest in "social science" issues around earthquakes has increased significantly, fueled in part by multidisciplinary professional associations such as the Earthquake Engineering Research Institute (EERI) and their interest in more holistic understanding of earthquake impacts and the steps that communities might take to improve mitigation, preparedness, response, and recovery.

This increased interest in the human side of earthquake disasters is the natural outgrowth of observations that technical solutions alone are insufficient to drive the changes needed in communities to achieve the

objectives of improved mitigation, preparedness, response, and recovery. Illustratively, even when people know that particular areas are likely to be unsafe to live, they may choose to build their homes there because of tradition, cost, or access unless the prohibitions against doing so are sufficiently motivating and consistently enforced. Corruption in government and in the building trades can yield behaviors that are self-serving and lucrative for a relatively small group of individuals in the short-term and devastating to communities in the long-term as poor quality materials are swapped out for higher quality ones and inspectors are bribed to sign off on poor designs and shoddy construction. Human decision making is a complex field of inquiry; understanding why people think and act as they do is essential if we are to propose and implement the actions most likely to effect positive adaptation and growth before and after disasters.

Those who have participated in traditional earthquake reconnaissance know that many of the social science issues faced by a community may not manifest in the early days between response and recovery. Thus, improving our understanding of community recovery would seem to demand a different type of earthquake reconnaissance in addition to the traditional type. Related to this is the burgeoning interest in the concept of community resilience and the means that may be undertaken to measure, understand, and enhance it. As defined by Tremayne and her colleagues [6], resilience is "the ability of a community to maintain functionality (i.e., a core set of vital services and functions) in the face of a wide range of stresses and shocks" (p. 2).

One means for assessing community resilience is resilience reconnaissance in the aftermath of a disaster, where the disaster represents an acute shock to the community's interdependent systems. Resilience reconnaissance requires adaptation of the traditional earthquake reconnaissance model. Its purpose is "to understand how an earthquake affects the continuity of different services and functions and how disruption of these vital services and functions impacts different groups within a community" (p. 1) [6]. By itself, this definition may not appear to suggest anything different. It's the next part of the definition that makes clear the essential difference between traditional and resilience reconnaissance. Specifically, resilience reconnaissance requires "field investigations that span the dimensions of time, space, and perspective" (p. 1) [6]. In other words, resilience reconnaissance looks at services and functions at different times (e.g., before an earthquake, immediately afterward, and during the response and recovery phases), across different spatial scales (e.g., from buildings to neighborhoods), and as perceived by different stakeholders (e.g., producers, consumers, and regulators). Briefly, resilience reconnaissance requires an approach that goes beyond one-time field investigations in the relatively immediate aftermath of an earthquake that look primarily at the earthquake's impacts on the natural and built environment from the perspective of technical experts.

While traditional earthquake reconnaissance has evolved and been refined over the course of many decades, resilience reconnaissance is relatively new and protocols for its effective implementation are not yet fully developed and tested. While theory development in this arena is critical, field investigations are also needed to assess the utility of resilience theory as it relates to disasters and the challenges that may need to be addressed before it's possible to "draw conclusions about the resilience of impacted communities, (identify) lessons learned to be shared with other communities, and (articulate) newly identified research needs" (p. 3) [6]. Numerous challenges face those hoping to conduct resilience reconnaissance. Like all longitudinal research, resilience reconnaissance requires an early vision of what might be valuable to study over a longer term and the ability to identify valid and reliable indicators that can be measured at multiple points in time. It requires the human and financial resources to support multiple investigations over a long-term time horizon. It demands consideration of interdependencies through an interdisciplinary lens – something that most technical experts have not been trained to do. It relies on first-person accounts that may be difficult to acquire as the people who lived in a given community before an earthquake may no longer live there as time goes by, perhaps because they have been a casualty of the disaster or because they have been displaced. Despite these and other challenges, resilience reconnaissance is likely to become more common as researchers seek refined understanding of the factors most likely to affect recovery and resilience.

3. Methodology

3.1 General Overview

The research described in this paper contributes to the evolving literature on resilience reconnaissance. The first author, a structural engineer, was involved in the design and construction of homes and schools in several villages in and around Banda Aceh in the aftermath of the 2004 earthquake and tsunami. Nearly 15 years later, in September 2019, he returned to Banda Aceh, visiting six villages and making personal observations of the built structures featured in this research. In addition, using contacts made during his earlier time in Banda Aceh, the first author interviewed the occupants of nine representative homes along with the principals of six representative schools. Research participants were all asked a series of questions, with assistance from a native translator (Figure 1). The overall goal of the interviews was to encourage participants to tell their stories in their own words, with minimal prompting from the researcher.

Questions for Homeowners	Questions for School Principals
• How is this house different from what you had before?	• How is this school different from what you had before?
• Who built your house? When?	• Who built this school? When?
• What do you like most/least about your house?	• What do you like most/least about this school?
• Is this house easy to care for?	• Is this school easy to care for?
• Have you made repairs? If yes, describe.	• Have you made repairs? If yes, describe.
• Does this house feel safe to you? Explain.	• Does this school feel safe to you? Explain.
• Has the community recovered from the tsunami?	• Has the community recovered from the tsunami?
• How has the community changed since 2004?	• How has community changed since 2004?
• What took the least/most time to return to normal? Anything that has not done so?	• What took the least/most time to return to normal? Anything that has not done so?
• Who has best helped the community recover?	• Who has best helped the community recover?
• Do you think about whether another tsunami is possible and what might happen? Do you know what to do in the event of another tsunami?	• Do you think about whether another tsunami is possible and what might happen? Do you know what to do in the event of another tsunami?
• How would your community respond to and recover from another tsunami?	• How would your community respond to and recover from another tsunami?

Figure 1. Questions asked of research participants

Participant responses were translated by a native translator and written by the first author who also took photos of homes and schools. The in-country methodology used for this research is consistent with that used in traditional reconnaissance whereby a walking survey of the built environment is undertaken in representative locations considered likely to yield valuable insights into the broader community's response. In this case, the first author visited areas that were affected most negatively along with sites that he helped to reconstruct in 2005-2007. The order of the visits was based on proximity and ease of access.

3.1 Research Itinerary

The walking survey was conducted over four full days.

Day 1. The research started in the village of Kajhu with interviews of homeowners. While the first author tried to find the houses he had worked on and where he had interviewed the homeowners in 2005 and 2006 on the designs to be built, it proved almost impossible to find these houses with the area built up since then and the changing of the people living there. There were at least twice as many houses with still more being built. The research continued in Ulee Lheue, one of the worst hit areas in Banda Aceh. Unfortunately, the team was only able to find one homeowner who was there before the tsunami and home to talk. Other homeowners were newcomers who could not offer a perspective on the community prior to the earthquake

and tsunami. The next stop was Peukan Bada. In addition to interviewing homeowners there, the team also visited the new Tsunami Vertical Evacuation Structure that was built by the government of Japan.

Day 2. The research focused on schools in several villages. The team visited Peukan Bada (in the City of Banda Aceh) and Tanjung, Lamkruet, and Mon Ikeun– all in Aceh Besar. The schools were picked due to their location along the only route between Banda Aceh and the West Coast. The team ended Day 2 in Lampu'uk on the West Coast, where only a few hundred people survived out of more than 7,000. The team was not able to interview anyone at a school there, and it was difficult to find a family that was there before the tsunami. While most of the villagers were killed, most of the others who survived had left in the aftermath and newcomers had moved in. The team did find one older couple that was there before and after and interviewed them. The team observed that about half the houses in the village had been abandoned.

Day 3. It was a holy day so the team was limited in what it could do. They visited another Tsunami Vertical Evacuation Structure and searched without success for Oxfam-built houses near Kajhu. The team looked at some other housing developments that were under construction. Later, the team visited Keanue Ue where Build Change built its very first houses since forming as an NGO as part of a pilot project[1].

Day 4. The team visited Neusu village in the City of Banda Aceh and surveyed a UNICEF/UNOPS-built school (Type 1 design). The team also visited a school in Lamprit village, part of the City of Banda Aceh. This school used the UNICEF/UNOPS Type 2 school design.

3.2 Village Descriptions

Homes and schools in six villages in close proximity to the City of Banda Aceh were studied.

Lampu'uk and Lhoknga. Both were subjected to some of the worst effects of the tsunami with waves reaching nearly 30m high. The two villages are located 13 km to the southwest of Banda Aceh and along the west coast. They are officially outside the Banda Aceh jurisdiction, in a regency called Aceh Besar. Lampu'uk was made famous by the press in the days after the tsunami, as it was the location of a single mosque that was still standing when nearly everything else around it had been erased. Aerial photos of this village were broadcast around the world by major media. Much has changed there since 2004 (Figure 2).

Figure 2. Lampu'uk immediately after the 2004 earthquake and tsunami and Lampu'uk in 2019

During its recovery, Lampu'uk acquired the nickname of "Turkish Red Crescent" village, since the Turkish Red Crescent seemed to be the only NGO rebuilding there. Rows of "cookie cutter houses" were built, all with a large 2ft in diameter glazed Turkish Red Crescent logo above the front door. Even the street signs

[1] The first author was a member of a team of engineers in late 2005 and early 2006 that designed a safe, constructible, low-cost house. He went to the site in mid-2006 to oversee final designs and construction, moving there in fall 2006 as Build Change's "Design and Construction Engineer." He worked for Build Change until May 2007 and for UNOPS until March 2008 as the head of its Technical Support Unit in Banda Aceh.

were branded with the logo. The Turkish Red Crescent was viewed negatively by many because of the heavy branding and the number of homes built for families where all or at least all adult family members were deceased. The Turkish Red Crescent was one of the few NGOs that started rebuilding very early. Some locals believe that the Turkish Red Crescent wanted to rebuild as many homes as possible at the expense of proper coordination with the Indonesian authority in charge of the reconstruction, BRR (Badan Rehabilitasi dan Rekonstruksi Aceh-Nias). By doing so, they could report impressive numbers to donors back in Turkey.

Ulee. Officially, Ulee Lheue, Ulee is a village in the City of Banda Aceh. It is located near the coast and port and is surrounded by inlets on either side. This area was hit hard by the tsunami and saw the front of the wave as it headed inland to the rest of Banda Aceh. One of the NGOs responsible for rebuilding in this village was World Vision, a Christian-based NGO.

Kajhu. Kajhu is a sprawling village that sits to the east of Banda Aceh (also in the Aceh Besar Regency, Aceh Besar wraps around the City of Banda Aceh jurisdiction). Kajhu was also hit hard by the tsunami. Locals interviewed by the first author in 2006 describe the wave hitting their village higher than some of the trees that were still standing (over 25-30ft). Kajhu was reduced to rubble after the tsunami, with no built structures left standing. The first author worked in Kajhu with Build Change. Build Change had a partnership with Oxfam GB to design and build homes using Oxfam's funding, allowing Build Change to extend its impact. While working for Build Change, the first author was responsible for managing homeowner interactions and conducting village meetings (with help from a native translator) where homeowners were asked for input on the design of their house. Oxfam/Build Change was one of many NGOs in Kajhu.

Peukan Bada. Peukan Bada is located in the City of Banda Aceh on the western side; it is surrounded/bordered by wetlands, which lead to the inlets and ocean. A large section of Peukan Bada was rebuilt by CRS (Catholic Relief Services, an NGO based in Maryland, United States). The first author was involved with the CRS houses in this village, as many had been built with defects that jeopardized their seismic safety. Build Change worked with CRS to develop a way to retrofit the houses even at a loss, since demolition was seen as a public relations nightmare.

Keanue Ue. While Keanue Ue was not subjected to the tsunami, it was affected by ground shaking from the earthquake. This village was picked as Build Change's pilot project location when it started out. Only three houses here were built by Build Change as part of its pilot project in late 2005-early 2006. In one case, though the homeowner's original house remained useable, a new one was built. This was a rare occurrence, as normally, the owner had to lose their house completely in order to receive a new one.

4. Findings

Through observation and interviews, it was evident that much of the rebuilding that occurred in Banda Aceh and nearby villages was fueled by a "build back better" mentality, meaning that the government, NGOs, and private donors hoped to change the affected communities such that issues that existed before the tsunami (e.g., poor quality construction, buildings in high-risk locations) might be reduced in degree or eliminated. The first author experienced this mentality firsthand during his time in Banda Aceh (2005-2007); interviews with this study's participants confirmed the dominance of this thinking. It was an explicit goal of many of the organizations responsible for providing funding that the newly built structures should be sustainable and not affected by the corruption and problems associated with pre-tsunami construction.

4.1 Structural Observations

Concrete. There was no observable degradation of the concrete used in the schools or homes, with the exception of the SNAN1 Lhoknga School built by Mercy Malaysia (Figure 3). Much of the concrete spalling in this school was due to rusting of the rebar which was due to improper concrete cover (the amount of concrete the rebar is buried under, to protect it from moisture in the air). For the other schools, concrete structural elements showed little to no signs of spalling as a result of rebar rusting and swelling. Concrete floors also showed little to no signs of cracking or spalling (with the exception of Tanjung School)

Figure 3. Concrete spalling at SNAN1 Lhoknga School

Wood/timber elements. Most houses had significant wood rot and termite infiltration in the wooden doors and/or door jambs. Schools had broken wooden doors, but most of the vents and window frames were still intact (Figure 4). Most of the school buildings and home roofs had wood rot in the roof fascia and soffit timber boards to the point where parts of it were now dangling down, or had completely fallen off (Figure 5). The type and source of wood used was not able to be verified.

Figure 4. Typical wooden door at SDN 25 in Lamprit

Figure 5. Rotting roof fascia and soffit timber boards, Kajhu

Ventilation in school classrooms. Based on observations, the classrooms seem to be well ventilated and there were no issues by the school headmaster.

Corrosion on steel elements. The UNICEF type 2 schools with an external stairwell for second-floor access showed little rust and performed well given the extreme humidity and marine environment (Figure 6).

Figure 6. Structural steel in stairs

4.2 Interviews with homeowners

Homeowners from nine homes were interviewed. Their homes were built by the Canadian Red Cross (n=2), World Vision (n=1), Catholic Relief Services (n=2), Turkish Red Crescent (n=1), Build Change/Mercy Corp (n=3) in 2006 (n=5), 2007 (n=3), and 2008 (n=1). For those homeowners who owned a home prior to the tsunami, most (n=5 of 9) commented that their former home had been larger and "stronger;" many had been constructed of timber vs. the concrete used in the reconstructed homes. At least one homeowner remarked that prior to the tsunami, the homes in their neighborhood looked different from one another whereas now their appearance was too similar. While they were glad to have a home, they also commented on aspects they did not care for: smaller spaces, missing elements (e.g., kitchen), poor workmanship (e.g., sewage systems improperly installed), room location (e.g., bathroom next to living room), and poor quality materials (e.g., rotting wooden window frames, cracking floors). Most described their new homes as being easy to care for, primarily due to the smaller size. Four of the homeowners had made no repairs (with the exception of one case where the homeowner had added tiles). Five had made significant repairs and adjustments such as adding a kitchen, expanding the bathroom, fixing doors, adding new paint to the walls or even removing a load bearing column (Figure 7). In one instance, the homeowner had demolished half of the donated house and rebuilt it the way the owner wanted, including building a larger bedroom and raising the finished floor level for flooding mitigation (Figure 8).

Figure 7. Homeowner in Ulee Lheue removed a load bearing column to open up the space.

Figure 8. Homeowners in Peukan Bada who mostly rebuilt their donated house

With respect to their homes' perceived safety, 78% said they thought their home was safe because nothing bad had happened since they had been it. Some noted that their home had performed well after the magnitude 8.6 (Mw) earthquake in 2012. One commented that she knew the house was safe and strong because she had personally observed its construction. Still, one shared a concern about being located too close to the sea and two remarked on cracks in the foundation that made them suspicious of the building's safety.

All but one responded in the affirmative when asked if their community had recovered from the 2004 tsunami. When asked how their neighborhood had changed, homeowners commented on the different style of homes (no more wooden houses), newer infrastructure, the influx of newcomers (i.e., people from outside Banda Aceh), and changes to the economy. The most common responses focused on the changing demographics, not a surprising reaction given the extraordinary number of people killed and displaced by the tsunami. In terms of what took the least time to return to "normal," more than half referenced aspects of the built environment and the economy. When asked what had taken the longest to return to normal and whether there was anything that hadn't done so, they talked about the emotional and mental trauma of losing their family members, friends, and the strong sense of mutually-supportive community that had been dominant prior to the tsunami. They named themselves, NGOs, the government, and God as the agents of recovery.

Homeowners' perceptions about future tsunamis and their preparation was mixed. Some felt as though they had received adequate training about what to do and that they would be able to act appropriately. Others felt that no amount of training would overcome the likely panic. Some stated that they didn't expect that another

tsunami might occur and, if one did, they would simply run to higher ground. Those living close to a vertical evacuation structure said they would run to it. One homeowner said that another tsunami might be possible in another 100 years since that was the amount of time that had elapsed prior to the 2004 tsunami.

4.3 Interviews with School Principals

Principals from six schools were interviewed. Table 1 lists some of the characteristics of their schools.

Table 1. School characteristics

Name	Location	Number of Students	Responsible Builder	Year Built
Senior High School SMAN1	Peukan Bada	408	Turkish Red Crescent	2006
SDN 1 Tanjung	Tanjung	62	Turkish Red Crescent	2006
SNAN1 Lhoknga	Lamkruet	170	Mercy Malaysia	2007
SMP Mederi 1	Mon Ikeun	291	PKPM*	2007
SDN 34**	Neusu, Banda Aceh	120	UNICEF	2006
SDN 25	Lamprit, Banda Aceh	271	UNICEF	2009

* Pusat Kajian Pendidikan dan Masyarakat
** Formerly, SDN 96

Asked what they liked about the current school building(s), principals cited its location, the shape of the building, the design and number of classrooms, the layout, the availability of a library and computer lab, the overall construction quality, and the fact that the classrooms were made from concrete. This latter point is significant and reflects a cultural value in Indonesia. Specifically, concrete buildings are perceived to be more modern and permanent and therefore, they have higher social status – despite potential seismic disadvantages. Wooden or other light-framed structures are often considered temporary or old-fashioned and are likely to be rejected. Even having a stud-framed partition wall in a concrete building is frowned upon. For this reason, Indonesian contractors may be more familiar with concrete construction techniques.

With respect to issues, the principals said that the offices were too small and the step heights were too high for smaller children. They disliked the choice of fencing versus a solid wall to separate the school from neighboring buildings, the lack of tiled flooring in the classrooms, and the lack of a student hall. Most agreed that the building was relatively easy to care for, though they expressed concerns about the funding that would be needed in the future to make upgrades and to allow for more students (e.g., adding a second story) since the NGOs that paid for the buildings had moved on. All of the schools had been repaired since they were built. Most related to leaking roofs and ceilings, floors that needed attention because of cracking, replacement of steel railings that had corroded, new paint, and the addition of window bars.

With respect to their schools' perceived safety, five of six principals said they thought their school was safe because nothing bad had happened since they had been it. Some noted that their school had performed well after the magnitude 8.6 (Mw) earthquake in 2012. Sadly, one of the principals shared that she had lost her children to the 2004 tsunami and as a result, she found it difficult to think about the school's relative safety.

Two-thirds of the principals agreed that their community had largely recovered from the 2004 tsunami. The others noted that trauma remained a part of the community fabric and that for those who had lost family members, the recovery would never be complete. When asked how their community had changed, principals commented on the different style of buildings (concrete rather than wood timber) and shared their perceptions that the economy had been steadily improving and that the community had more and better quality buildings than before the tsunami. In terms of what took the least time to return to "normal," most of the principals referenced aspects of the built environment and the economy, just as the homeowners had. They also noted the availability of programming that helped community members manage their trauma.

When asked what had taken the longest to return to normal and whether there was anything that hadn't returned to normal, the principals spoke about the loss of elders and their knowledge to the tsunami, and the

negative impacts on the community's culture as a result. The principals also talked about the trauma faced by those who lost family members and friends and the triggers that cause continuing anxiety. Related to this, one of the principals shared the statistic that the student count at her school (SNAN1 Lhoknga) before the tsunami had been 700 and was now 170, a startling 75.7% reduction in the student population (Figure 9). For some children who lost a parent, the remaining parent remarrying was a catalyst for psychological stress. They agreed with the homeowners that many of the houses were smaller than the pre-tsunami houses had been and finding a sufficiently secure livelihood had been a challenge for some. The principals named their community's spiritual leaders, psychologists, NGOs, the government, and donors as agents of the recovery.

Figure 9. SNAN1 Lhoknga

The principals' perceptions about future tsunamis and their preparation was mixed. Some felt as though they had received adequate training about what to do and that they would be able to act appropriately when needed. All were focused on what they would try to do to ensure their students' safety. Others felt that no amount of training would overcome completely the likely panic and chaos. Some stated that they didn't expect that another tsunami might occur and, if one did, they knew to move to higher ground. Those living close to a Tsunami Vertical Evacuation Structure said they would run to it. All agreed that another tsunami was possible, noting that it was essentially God's will to decide whether such a disaster would recur.

5. Conclusions

5.1 Resilience Themes

A project recently completed by EERI's 2017 class of Housner Fellows focused on enhancing tools that might be used for resilience reconnaissance. They asserted that "a critical component to effective resilience reconnaissance is finding the themes or stories that underlie more readily observable issues; essentially, effective resilience reconnaissance should aid in revealing the iceberg underneath the visible tip" [11]. Trying to discern key themes is challenging and requires that researchers combine (1) their observations of the natural and built environment with (2) knowledge gained through direct sources (e.g., interviews of key stakeholders), and (3) knowledge available from indirect sources (e.g., technical reconnaissance reports).

The first of three themes that emerged from this research deals with NGOs. Specifically, while serving a critical role in the aftermath of the disaster, it was clear that not all members of the community understood the NGOs' roles and for how long they might be present in the community. Further, comments from our research participants suggested that not all NGOs were equally committed to consulting with community members when making decisions. Not consulting with community members led to confusion and the unexpected need to find more resources than they had available in order to repair and renovate the buildings donated to them by the NGOs. Essentially, while people were grateful to the NGOs, they also wished to have relationships that were more collaborative, from design through construction. Whether all of the NGOs had the resources to tailor their designs or modify their construction practices to align with end-user expectations

and cultural considerations is unknown. It was also the case that the aid provided by the NGOs and others was insufficient by itself to ensure long-term recovery and resilience.

The second theme that emerged deals with perceptions of recovery. While those interviewed recognized that the built environment had recovered quickly, they also spoke about the lingering trauma and emotional distress that remained top of mind for those who had survived the disaster. Whether due to grieving for lost family members and friends or wishing for other parts of their past (e.g., how their homes had been), it was clear from the interviews and based upon the team's observations that full recovery remained elusive 15 years after the disaster. This finding has implications for the type and timing of counseling services that government and other organizations might offer after a disaster. Despite training and education, most of the research participants still believed that another major earthquake and tsunami would yield panic and chaos – and that they had little or no agency with respect to whether another major event might happen in their lifetimes and whether they could proactively plan and effectively respond. This may be, in part, a function of the research participants' religiosity, as suggested by the comments about God's will.

A final theme that emerged is that, despite the hope that communities might "build back better" after a disaster, the pre-existing community reality will condition the probability of an approach's effectiveness no matter the amount of funding poured into the community [12]. As asserted by Arendt and Alesch [10], the *ex-ante* state of the community conditions post-disaster outcomes. In the case of Banda Aceh,

> "Nearly 500 agencies teamed up to raise an unparalleled amount of funding at that time that totaled up to $7.7 billion. Within a four-year period, they prioritized newer and stronger infrastructure for the province and built 140,000 homes, close to 3,700 kilometers of road — including the western coastal highway rebuilt by USAID — 1,700 schools, 1,000 government buildings, and 36 airports and seaports. The physical spine of Aceh was spectacular; however, under tight deadlines and pressure from private donors for visible results, there were no quick fixes for tackling long-term drivers of vulnerability such as livelihood and social recovery. Now, 15 years later, gaps in post-disaster recovery are still visible. Unable to sustain growth despite the infrastructure, Aceh remains extremely poverty-ridden … with a slow economy and high unemployment rate (para. 3)" [12].

This idea that "building back better" needs to consider more than the built environment is important for governments, NGOs, and private donors to act upon. The built environment, while critical, is only part of the community recovery and resilience equation. Other aspects of the community – its demographics and its political/governmental, economic, social, and cultural health – together determine the community's ability to recover [10]. This understanding, in addition to the other themes uncovered by this research, highlights the value of deploying interdisciplinary teams for traditional earthquake reconnaissance and supporting resilience reconnaissance efforts that "span the dimensions of time, space, and perspective" [1].

5.2 Limitations and Opportunities for Future Research

This research is exploratory, built upon the first author's experiences in Banda Aceh in the near-term aftermath of the 2004 earthquake and tsunami, and relies heavily on testimony from community participants who were available to be interviewed when our team was in-country. The number of participants is small, reflecting the challenges of conducting a walking survey over a short period (four days) in a community that has lost significant numbers of the people who lived in the community before the event. Whether the information gathered generalizes to the greater population of Banda Aceh or elsewhere is difficult to assess. To address this, more research seems appropriate. Further, it would be valuable to work with researchers in-country who could interview more community members, more often, and over a longer period and in more areas without the costs and other challenges associated with travel in a country to which one does not belong.

6. Acknowledgements and a Final Observation

We would like to acknowledge and thank the school principals and homeowners in Banda Aceh and Aceh Besar for their kindness, openness and most importantly, their time and willingness to recall a difficult and terrifying time of their lives. We would also like to thank Cici Amalia for her local knowledge, excellent

English-Indonesian translation skills, and ability to manage and focus the conversations of difficult topics. This research would have not been possible without her help. The people of Aceh have been very welcoming to outsiders, both right after the tsunami and today. The people of Aceh – victims of one of the worst disasters in modern history – are strong. The strength to continue with their lives after so much has been lost amazes us.

A final observation: It is clear that structural engineers are in high demand in earthquake recovery areas. While in Banda Aceh, the first author observed that most of the NGOs had no structural engineers with seismic backgrounds. We hope that more people with this knowledge and skills will share them with people in need such as those in Banda Aceh.

7. Copyrights

8. References

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