Community-Based Post-Earthquake Housing Re-Construction Using Building Ruins: A Case Study of Bantul, Indonesia

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abstract A 6.3 magnitude earthquake struck Bantul, Indonesia on May 26, 2006, causing immense loss of life and property. Approximately 37,927 people were seriously injured, 5,716 human lives were lost, around 156,664 houses were destroyed, and 202,032 were damaged. The total estimated loss during the Bantul earthquake was around IDR 29 trillion (US$ 3 billion). Non-engineered private buildings and houses were mostly damaged during the earthquake due to their high vulnerability to failure. This chapter focuses on the community-based post-earthquake housing reconstruction process in Bantul, using building ruins. The locals displayed a sense of solidarity, collectiveness, and tolerance during the disaster recovery process, which was recognized as a value adopted from their strong local culture. The chapter suggests the use of local practices. The Bantul community exhibited a great level of acceptance and comfort towards their new self-constructed homes using building ruins. Four levels of capabilities, namely attention (niteni), mimicking (niroake), adding (nambahake), and creativity (dan nemoake), have been explained to understand their independent construction using building ruins. The new buildings constructed after the earthquake presented an example of easy procurement of construction materials, self and simple construction, and a strong motivation to understand the sustainability of potential building material ruins. These are the actual requirements in any community for sustainable post-disaster construction

Keywords Ruins; Post-earthquake housing construction; Community participation

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Introduction

Earthquakes are one of the deadliest natural hazards witnessed on Earth in recent years, posing a serious threat to millions of people around the world. The world's eight to ten most populous cities are located around earthquake fault zones. Currently, the National Earthquake Information Center monitors 20,000 earthquakes a year, or roughly 55 per day, around the globe. One well-known active tectonic region is Indonesia, which is made up of three important active tectonic plates: the Eurasian plate in the north, the Pacific plate in the east, and the Indian Ocean-Australian plate in the south. Indonesia is particularly vulnerable to earthquake disasters due to its crucial placement at the intersection of three tectonic plates. In close proximity to the "Pacific Ring of Fire," Indonesia's 18,000 islands contain active volcanoes and tectonic faults on the islands of Sumatra, Java, Nusa Tenggara, and Sulawesi. There are more than 500 young volcanoes, 128 of which are active and makeup 15% of all active volcanoes in the world (National Development Planning Agency, 2006a).

On May 27, 2006, at 05:54 am local time, an earthquake of 6.3 magnitudes on the Richter scale hit the island of Java, Indonesia, about 20 km from Yogyakarta. It lasted for 52 seconds and caused ground shaking reaching a scale of VIII MMI (Modified Mercalli Intensity). Figure 2.1 shows the general map of Indonesia and the epicenter location of the earthquake. This earthquake is popularly known as the "Bantul Earthquake" owing to the serious damages caused in the Bantul Regency, Special Region of Yogyakarta, which is listed as one of the most earthquake-prone cities in Indonesia.

Geologically, Yogyakarta is located around the subduction zone between the Indo-Australian plate and the Eurasian plate. The epicenter of the Bantul earthquake was relatively shallow (33km underground), which resulted in more intense surface shaking than other deeper earthquakes of the same magnitude. The Yogyakarta and Central Java earthquakes affected roughly 1 million people, according to the International Recovery Platform (IRP), 2009, and BAPPENAS, 2006. Approximately 37,927 people were seriously injured, 5,716 human lives were lost, approximately 156,664 houses were destroyed, and 202,032 were damaged (Table 2.1).

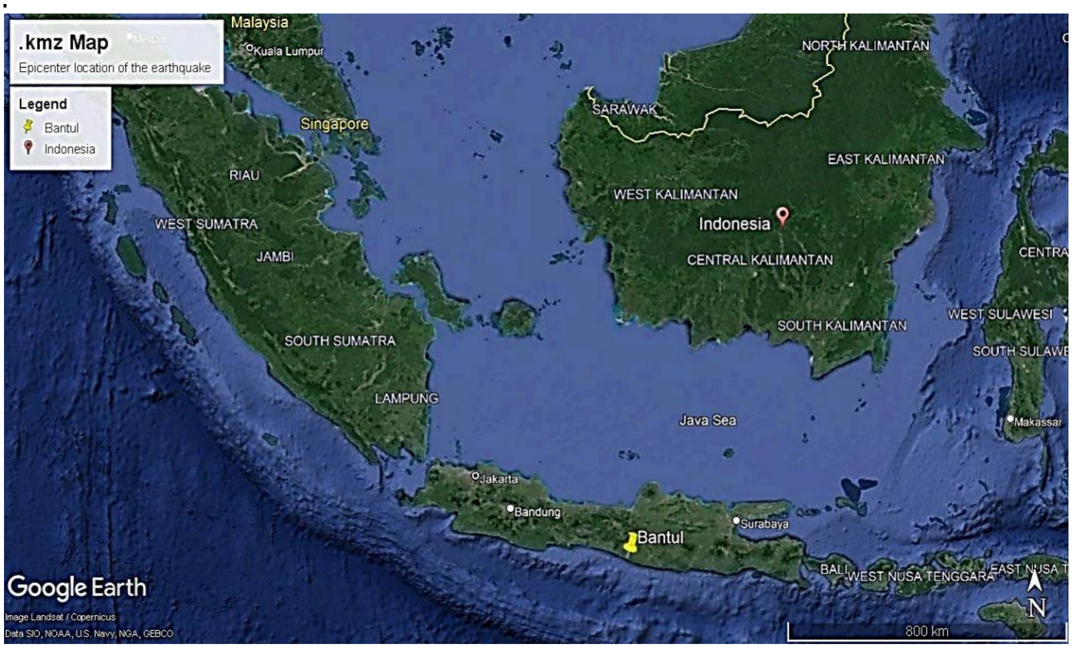


Figure 2.1. General map of Indonesia and epicenter of the 27 May 2006 earthquake (Map prepared using Google Earth)

Table 2.1. Distribution of casualties and housing damage by districts (BAPPENAS,2006)

Province and District	Casualties		Housing Damage		
	Death Toll	Number Injured	Totally destroyed	Damaged	Total
Yogyakarta Province	4,659	19,401	88,249	98,343	186,592
Bantul	4,121	12,026	46,753	33,137	79,890
Sleman	240	3,792	14,801	34,231	49,032
Yogyakarta	195	318	4,831	3,591	8,422
City	22	2,179	6,793	9,417	16,210
Kulonprogo	81	1,086	17,967	17,967	33,038
Gugung Kidul					
Central Java	1,057	18,526	68,415	103,689	172,104
Klaten	1,041	18,127	65,849	100,817	166,666
Magelang	10	24	499	729	1,228
Boyolali	4	300	715	825	1,540
Sukoharjo	1	67	1,185	488	1,673
Wonogiri	-	4	23	70	93
Purworejo	1	4	144	760	904
Total	5,716	37,927	156,664	202,032	358,696

The fact that Mt. Merapi's volcanic activity was intensifying concurrently with the earthquake made matters worse. Tens of thousands of people were evacuated as a result of the noxious fumes, ash clouds, and lava flows that were produced due to the volcanic activity. The Bantul Earthquake was Indonesia's third significant disaster in the previous 18 months. A major earthquake of magnitude 9.1 on the Richter scale and tsunami had already caused tremendous devastation in Aceh and Nias islands on 26 December 2004, followed by another earthquake on 28 March 2005, of magnitude 8.6 on the Richter scale that hit the island of Nias again.

Literature Review

The world has witnessed huge destruction in terms of lives and property caused due to the increasing frequency of natural disasters (Shaw, 2006). The disasters have had more impact on developing countries than developed ones (Ofori, 2002; Guha & Sapir, 2004; Ponnusamy, 2010), both in terms of immediate effects after the disaster, and through extended suffering during reconstruction and rehabilitation (Lloyd & Jones, 2006). Notably, there is an increasing threat of the frequency and intensity of natural disasters due to the alarming climatic changes that the world is facing (Helmer & Hihorst, 2006; Barnett, 2007; Salehyan, 2008). Earthquakes, however, are not directly related to climatic changes, but the risk of ever-increasing earthquakes can be mainly attributed to the increase in population, urbanization, and unregulated construction. Every disaster is associated with the generation of tremendous amounts of waste due to deaths and injuries, property damage and collapse, and crop destruction (Lindell & Prater, 2003; Shaw, 2006). Therefore, a considerable amount of the total cost of disaster management is spent on recovery, reconstruction, and rehabilitation, including debris management (Pike, 2007).

The Federal Emergency Management Agency (FEMA) defines disaster debris as: "Any material, including trees, branches, personal property, and building materials on public or private property that is directly deposited by a disaster."

According to the literature, there are some instances where the amount of debris produced in a single incident is five to fifteen times larger than the average amount of waste annually produced by the disaster-affected area (Reinhart & McCreanor, 1999; Brown, Charlotte, Mark & Erica, 2011). Ervianto (2012) suggests that building blocks produce various building materials like wood, concrete, bricks, metals, etc. that account for 75% of total waste. These wastes can be effectively used in the construction process. Among the various types of debris generated during an earthquake, the wide availability of building ruins is suggested by literature (Setyonugroho, 2013; Adriani, 2013). Westover (2009) states that the rubble piled around the buildings after an earthquake is the main sight post-disaster. The characteristics of the debris – type and position, are understood by the description of the ruins. Based on these characteristics, the utilization of demolition material in post-earthquake construction has been suggested (Lizarallde, 2006). When seen in a post-earthquake setting, building materials are unquestionably available in various dimensions and types than under normal circumstances. According to Syukur (2008), the typology of building material ruins is based on form components and functional components in the situation of damaged building materials that were acquired after an earthquake. In certain earthquake-hit communities, people tend to collect, select, and reuse the building material debris based on its condition and specific use (Marcella, 2011). Setyonugroho (2013) explains that post-earthquake construction starts with the cleaning of debris, sorting it, and finally shifting the useful building materials that can still be used in construction. The use of building debris is associated with limited natural resources availability and thereby it is imperative to take advantage of the used building materials that are feasible, without compromising the structural integrity of the building.

In Bantul, Indonesia, after the 2006 earthquake, the practice of reusing building material from the ruins for post-earthquake housing construction was observed to be effective and beneficial. The victims who were severely affected by the disaster provided valuable insight into the practice of reusing material ruins while constructing their own homes (Sunoko, 2008). The concept of using building ruins in self-construction activities during post-earthquake housing construction has been studied in Bantul, and the practice was termed "architecture without architects." Although many researchers have discussed the post-earthquake scenario in Bantul, a comprehensive study involving all aspects of reconstruction has not been presented together.

This chapter aims to highlight the community-based post-earthquake housing reconstruction method in Bantul, Indonesia, by understanding the necessities, approaches, techniques, methods, and outcomes of this practice. The main purpose is to present a comprehensive idea of what the local community can do to ensure a sustainable reconstruction process. It tries to emphasize the necessity for immediate rehabilitation after any disaster and how the local community can provide manpower and local techniques to save time incurred in rehabilitating a large population after an earthquake. This practice can aid the rehabilitation and reconstruction programs of the government in terms of time, manpower, and cost incurred in the process.

Furthermore, the level of acceptance demonstrated by the locals of Bantul towards living a simple life is noteworthy. It is the most important takeaway for any disaster-hit community to overcome its sufferings and productively contribute to sustainable construction and rehabilitation after any disaster.

Economic Loss

A disaster is an event that can be natural or manmade, or progressive suddenly, which causes a profound impact such that people affected or unaffected need to respond with exceptional measures (Fiedrich & Burghardt, 2017). Disasters are frequently dismissed as part of trivial discussions before they happen. It sometimes causes casualties and property losses beyond one's analytical capabilities. During earthquakes, it's most often the buildings that cause most of the destruction especially if they are impoverished and in abundance across a densely populated place like Bantul, Indonesia. In a place like Bantul, the paradigm "Earthquake does not kill people, but buildings do" goes well with its disastrous situation.

Bantul, which occupies 506.85 km^2 (15% of the province's total size), is situated in the southernmost region of Yogyakarta. Bantul Regency had 820,541 inhabitants in 2004 and a population density of 1,611 people per square kilometer (Statistics Centre Bureau, 2008). The Bantul earthquake, in 2006 occurred due to intense pressure between Indo-Australian and Eurasian plates and was one of the most destructive earthquakes that the people of Indonesia had ever experienced. The maximum population in Bantul is involved in small-medium enterprises (SMEs). Being one of the developing country, Indonesia already faces various urban issues like population growth, urban sprawl, a weaker economy, and dense construction while it is facing serious threats of earthquake disasters. According to National Development Planning Agency's 2006b report, the earthquake caused 246% total damage and losses by value when compared to Bantul's gross domestic product. A comprehensive study by the Indonesian government and international experts has estimated a total loss of around IDR 29 trillion (US$ 3 billion) during the Bantul earthquake (National Development Planning Agency, 2006Yogyakarta, and Central Java's building characteristics have been divided into two categories: engineered and non-engineered buildings (Boen, 2006). Since non-engineered private buildings and homes are more prone to collapse because of improper building code implementation in developing nations, these structures sustained the majority of the earthquake's damage. Literature suggests that more than half of the total damage cost and losses were accounted for private homes. Around 157,000 houses were destroyed completely and 203,000 suffered serious damage making them inhabitable. The anticipated losses in public and private infrastructure were estimated at Rp 397 billion and Rp 153.8 billion, respectively (National Development Planning Agency, 2006b). The economic breakup can be understood by the graph presented in Figure 2.2. The earthquake left over 5,800 people dead, 38,000 injured and even more people homeless. This necessitated the need for immediate steps to be taken for the rehabilitation and reconstruction process. Thousands of damaged houses were to be rehabilitated and reconstructed. This large-scale housing reconstruction effort is identified as the most challenging and problematic activity during the recovery phase. It is considered the most crucial factor for restoring normalcy in any community after a disaster (Peacock *et al.,* 2007). Any delay can hamper other recovery effects such as social, economic, and psychological effects (Barakar, 2003; Lindell & Prater, 2003). The relevant bar chart is shown in Figure 2.2.

Issues in Post-earthquake Housing Construction

Effective post-earthquake management is crucial and directly correlated to the overall success of the recovery process in a disaster-hit area. The identification of dwellings that are still structurally sound and maneuvering to assuage the need for temporary housing are quite important. Petterson (1999) suggests that local design details become an important parameter for post-earthquake recovery. Additionally, it has been highlighted by Ranganath (2000) that people do not always favor the engagement of experts from unaffected areas in the development of strategies for impacted communities. This is a result of the perception that the value of the neighborhood working together to solve its problems through collaboration and understanding to meet the needs

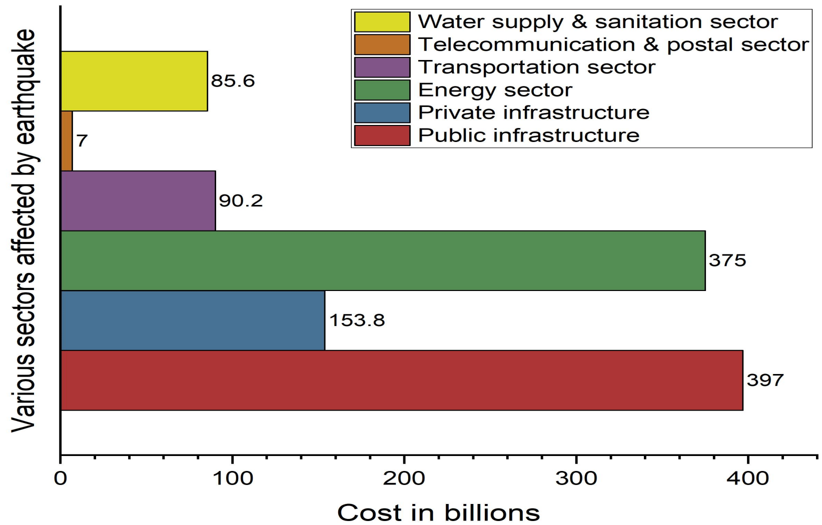


Figure 2.2. Damage and losses to various sectors after the Bantul earthquake (National Development Planning agency, 2006b)

of the neighborhood's residents is being undervalued. The post-earthquake housing construction process in itself is a task, and many issues are associated with it. A brief idea of such issues is presented here to better implement housing construction ideas in practice for areas like Bantul, which are prone to earthquakes now and then. The various issues associated with post-earthquake housing construction include:

a. Long-drawn rebuilding procedures: Rebuilding a damaged property requires vast financial aid, technical expertise, time, and emotional support in comparison to constructing new buildings.
b. Failures during resettlement: The choice of land for resettlement after an earthquake is very crucial. Generally, easily acquired government land is used for a purpose that may not be a good habitable site. Also, the reconstructed projects in many cases fail due to a lack of consultation with the occupants of the houses as a result of the communication gap between the planners and the locals.
c. Holistic planning: The participation of people is crucial for post-earthquake housing construction. The planning should encourage cooperation between the locals and the environment. Sustainable development, which includes minimizing environmental harm and the use of non-renewable resources, is the goal of holistic planning.
d. Sustainability: Construction practices should focus on reduced energy flow, waste generation, and material use. Buildings should preferably be made using any possible recyclable material while maintaining the durability of the structure. Also, the use of local skilled labor is a good practice to follow.

Community Participation

The term community has been explored by Lee and Newby (1983), Willmott (1986), and Crow and Allen (1995) in three different ways as cited by Smith (2001). They include:

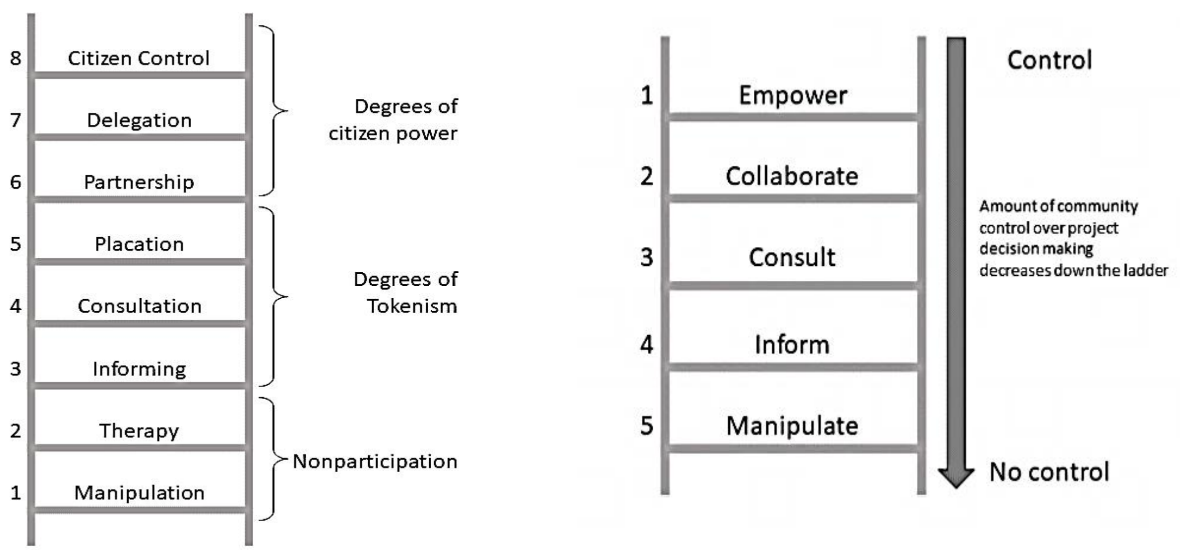
A. Place: Place community or 'locality' is where people have something in common which can be understood geographically.
B. Interest: An interest community or 'elective' community is where people are linked by factors like religion, occupation, ethnic origin, or sexual orientation.

C. Communion: It explains the 'spirit of community' where people have a sense of attachment to a place, group, or idea.

The word 'community" has been defined in a number of ways, and Hillery (1955) cited that Kumar (2005) states 94 varied definitions exist in scientific literature, among which McMillan & Chavis' definition is the most widely accepted one. They consist of the four components of a sense of community, i.e., membership, influence, integration, fulfillment of needs, and shared emotional ties. According to McMillan & Chavis (1986), "Community is a feeling that members have of belonging, a feeling that members matter to one another and to the group, and a shared faith that members' needs will be met through their commitment to being together."

According to Chambers (1983) in Kumar (2005), the emphasis on "community engagement" began to gain relevance in the 1980s with the advent of "participatory" approaches. However, Kumar (2005) cited Midgley *et al.,* (1986) as saying that although the term "community" was crucial to the problems with participatory development, it was poorly defined. According to Kumar (2005), it is unclear in "community" involvement programs if "community" is intended to be a means or an end to the developmental program.

In order to understand the level of participation in a community, Arnstein (1969) developed 'A Ladder of Citizen Participation' with eight levels of citizen participation [Figure 2.3 (a)]. Choguill (1996) later refined this model to better serve the needs of developing nations by categorizing the steps in community participation as neglect, rejection, manipulation, and support. Davidson *et al.,* (2007) merged the two theories to make these classifications appropriate for community involvement in housing reconstruction projects. According to Davidson [Figure 2.3 (b)], the degree of community input into project decision-making decreases as we move down the ladder. Any housing rebuilding initiative should at least reach the basic levels of empowerment and participation to qualify as "Community-Based" or "Community-Driven." This highlights the fact that beneficiaries can serve as managers or even contractors of their housing reconstruction project, in addition to being the owners of the same. This will allow them to construct their homes according to their needs.



(a) (b)

Figure 2.3. Ladder of community participation (a) Arnstein's model (b) Davidson's model

The idea of community involvement entails the public's readiness to contribute worthwhile suggestions in order to improve the caliber of public services to meet the needs of the area's residents. The idea of community involvement is nothing new for the local government of Bantul. Since 2000, it has made tremendous efforts to practice the involvement of the community in the development of Bantul. However, this concept flourished in 2006 post the Bantul earthquake, after which the locals who were unaffected or slightly affected took to their own feet and hands and planned to participate in the rescue, rehabilitation, and reconstruction process. The recovery programs in Bantul had a great deal of success because of the community's cooperation and high level of engagement. The confidence of government agencies to rely on the local public was due to the good social capital, *gotong royong*, which means cooperating among and between the social circles. Since the local community best knows their society and the development patterns of their specific areas, the community preferred to construct their own homes using their designs and preferred materials, which included earthquake debris. This was in accordance with Leuken suggests the process of creating any residential space should involve the user as they best know what suits their needs. The locals collected, selected, and used the earthquake ruins in their construction. The huge public participation and public insight minimized the potential conflict in Bantul and aided its recovery. Literature suggests that communities with firm working relationships better overcome emergencies during any disaster because of mutual trust and understanding (Kapucu, 2006) which is surely true for Bantul. They set up a Self-Reliant Housing Community Group wherein they planned, decided, and executed the rebuilding procedure using their resources, in addition to the Rp 15 million funds from the government. The government's fund was enough to build foundations, the framework of the superstructure, and roofing, while the components such as windows and doors were to be provided by the locals. Also, the requirement of labor was sufficed by the locals themselves. They promoted the idea of *Bagidil* instead of *Bagital*. While *Bagita* is the process of distributing funds equally among the recipients; *Bagidil* aimed at fairly distributing the government's funds based on the priority of eligible recipients. This was quite supportive of the people who were least affected by the earthquake to help the ones who had suffered enormous losses. This social capital in Bantul is an intangible resource that a community can have due to networking and trust among themselves (Field, 2008). Bolino *et al.,* (2002), Lin (2001), Nahapiet and Ghosal (1998) define social capital as: "Social Capital is the resource that is derived from the relationships between individuals, organizations, and communities, embedded in a social structure, mobilized in purposive actions and derived from the network of relationships possessed by an individual or social unit."

The shift of paradigm in Indonesia with respect to disaster management from its response to the recovery phase wasn't as easy as it seems. Prior to the 2006 earthquake, there was no strategic plan in place for effective coordination, disaster preparedness, mitigating the inadequate infrastructure, and information dissemination. Most victims affected by the earthquake were living in very low-quality houses, making them vulnerable to risks, however, they limited access to insurance (Samal *et al.,* 2005). No doubt, the Bantul government had framed certain disaster mitigation policies, but various studies suggest that the local community is more influential in developing such policies and their participation and ownership are much more valuable (Godschalk *et al.,* 1998; Okazaki and Shaw, 2003), hence the government involved the insights of the local community in policy-making after the Bantul earthquake. Community involvement was seen at the district, sub-district, and village levels while they were given a chance to decide on the rehabilitation type that would match their local needs. Due to the enhanced coordination and capacity building among the local community along with a better understanding of the recovery and rehabilitation problems, people in Bantul have potentially improved their post-disaster mitigation responses. This empowerment of the locals towards natural disasters is suggested to be a critical factor in the successful mitigation of disasters (Sharma *et al.,* 2003).

The people of Bantul stood as a strong and hardworking community to achieve their goals after the 2006 earthquake. They started their housing recovery program, and according to the Department of Public Works, they were successful in constructing new homes worth about Rp 35 million. The accomplishment of this rehabilitation program was made possible by the government's financial support of Rp 15 million and the substantial social capital of the Bantul community. Also, the aesthetic appearance of the houses was better than before, in addition to them being earthquake-resistant. The Bantul earthquake can be thereby called a “blessing in disguise” for the people of Bantul in particular and Indonesia in general.

The practice of Architecture without Architects

The recovery phase after any disaster is the most crucial. In Bantul, after the 2006 earthquake, a new dimension to the recovery and rehabilitation phase was witnessed by the world, where the local community aided the process of recovery using their local culture and wisdom. Some of the severely affected victims started the housing reconstruction process on their own, even before the financial assistance and involvement of the government, while they were assisted by other locals. A sense of solidarity, collectiveness, and tolerance was portrayed by the locals during the disaster recovery, which was recognized as a value they adopted from their strong local culture. The usage of material debris and the opinions of residents in the reconstruction process following the earthquake suggest the practice of "architecture without architects," with reference to Mentayani (2012) and the Empress (2013). They constructed shelters by reusing the ruins of buildings, which, in the long run, turned out to be quite suitable for their dwelling. It was, however, important to understand the relationship between the building material ruins to be used in reconstruction, the shape or form of the materials used, construction practices, and local wisdom. Sunoko *et al.,* (2018) suggest finding a method that was used by the locals during the construction and developing a more comprehensive understanding of the same so that it can lead to the development of more generic methods that can be used in post-earthquake architecture in the future. This type of construction is quite interesting and can be a suitable model to understand sustainable building construction. The peculiarity of such self-reconstructed structures is based on factors like the material used, construction skills, and the availability of funds. The role of rubble in meeting the requirements of post-earthquake housing construction is very dominant in Bantul. Table 2.2 suggests that an average of 86.47 percent of ruined building material was re-used by the people of Bantul. Even certain victims show an optimal tendency to re-use 100 percent of the ruins. Such high percentages speak to the coherent link between the processes of inventorying debris and its reuse. The intact ruins play the dominant role in deciding the plan area of the building during post-earthquake construction.

Figure 2.4 can provide a better understanding of the number of debris reused in post-earthquake housing construction. Brick building materials have a high tendency to be damaged and, therefore, cannot be used in construction. Similarly, bamboo is also unsuitable due to its aging. Most of the building ruins are dominated by wood. The locals prioritize using wood based on its availability, ease of construction, and practicality. Wood can be easily reused with no additional materials required, except for nails that can be obtained from remnants that have been trimmed. The cutting, if required, is mainly done using saws or machetes, and sickles are used in case there aren't enough saws. The process of cutting, splicing, and connecting refers to the habitual work of connecting wood by the local artisans.

The shortcomings of the main building materials obtained from ruins are compensated for by using local trees such as jackfruit, coconut, and melinjo trees by logging, sawing, and cleavage processes to obtain desired bars or boards from them.

Table 2.2. Use of building material ruins and new building materials (Surveys & Measurements, 2013 & 2015)

No.	Wall		Roof	Building Material Ruins (m^2)	New building materials (m^2)	Percentage of Building Material Ruins (%)
	Outside (m^2)	Inside (m^2)	(m^2)			

1	72.50	35.00	57.75	162.25	35.00	78.82
2	95.00	25.00	56.50	176.50	-	100
3	80.00	15.00	32.50	130.50	32.00	75.48
4	96.00	45.00	69.50	210.50	74.75	64.49
5	87.50	46.25	72.50	206.23	35.00	83.03
6	157.50	32.50	126.50	316.50	65.00	79.46
7	42.00	18.00	29.50	89.50	-	100
8	72.00	16.00	35.50	123.50	-	100
9	108.0	45.00	80.00	233.00	36.00	84.55
10	56.00	12.00	34.00	102.00	-	100
11	108.0	-	89.50	197.50	85	56.96
12	60.00	17.50	38.50	116.00	-	100
13	67.50	11.25	44.50	123.25	-	100

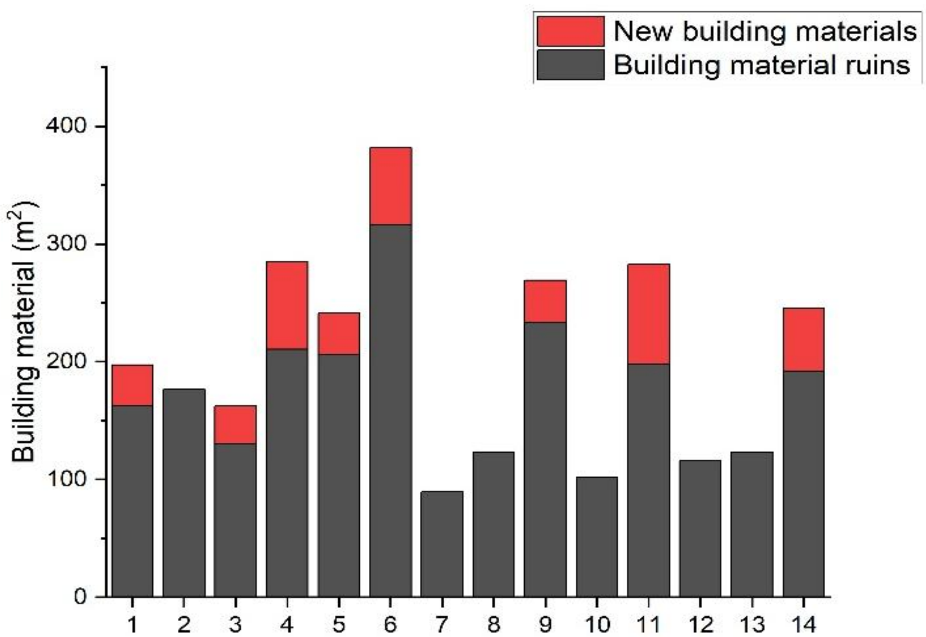


Figure 2.4. Comparison between the use of new building materials against building materials ruins in Bantul reconstruction (Surveys & Measurements, 2013 & 2015)

The victims of the disaster-hit Bantul collectively started the process of restoration by cleaning the site and conducting an inventory of the material debris, followed by construction. The manifestation of material state, form, and size is explained by Sunoko *et al.,* (2016) in terms of the local terminology used by the people of Bantul. "Wutuh-remuk" specifies whether the material is in a single piece or has been damaged, thereby describing the state of the material. A clear pairing between "wutuh" and "remuk" was observed in the study. A condition called "Kandhang" describes the erection of a building made from concrete columns that form a frame structure without using wall charger components and the construction of a wooden roof truss. The form material is explained by the state "dawa-cendhak" (long-short) which explains whether the material is available in its original length or has shortened due to any fractures. Based on this, the use of various elements can be suggested. Due to the failure of the building, the state of the material with respect to its shape is altered. While some still fit in their original shape, the majority suffer distortion in shape.

"Kukuh-gapuk" is used to explain this state of the material. In addition to this, reforming the material aesthetics and collecting back the furniture and other household goods to be used as filler buildings were also included. There was a certain sense of typology with respect to reusing building ruins in post-earthquake housing construction. Sunoko *et al.,* (2018) explain these typologies:

a. Use of materials from different types of buildings but used in the same function (typology type A).
b. Use of materials from similar types of buildings but with different functions (typology type B).
c. Use of materials from similar types of buildings and with the same function (typology type C).

Wutuh-Remuk: Method to Apprehend Post-Earthquake Artifact Ruins

During the initial stages of the recovery phase, the ability of the victim to map the potential artifact ruins is a crucial step toward re-utilizing the ruins. Victims describe the ruins as *donya* (wealth) even if it is not in a proper tangible shape to be used for building construction and believed it would provide *ajine* (value) to the post-earthquake housing construction. *Wutuh-remuk* described the state of shape and size of the material. *Wutuh* was used to describe the shape of material that was still in conformity with the original shape while *remuk* described the state of change in shape. The *wutuh-remuk* method enabled the locals to produce materials that were ready to use for construction. It provided a separation process for categorizing materials as functional, structural, and architectural materials. The materials responsible for providing structural strength were called structural materials. The ones responsible for the appearance were the architectural materials. Functional materials included the equipment and furniture for re-use as filler in the homes.

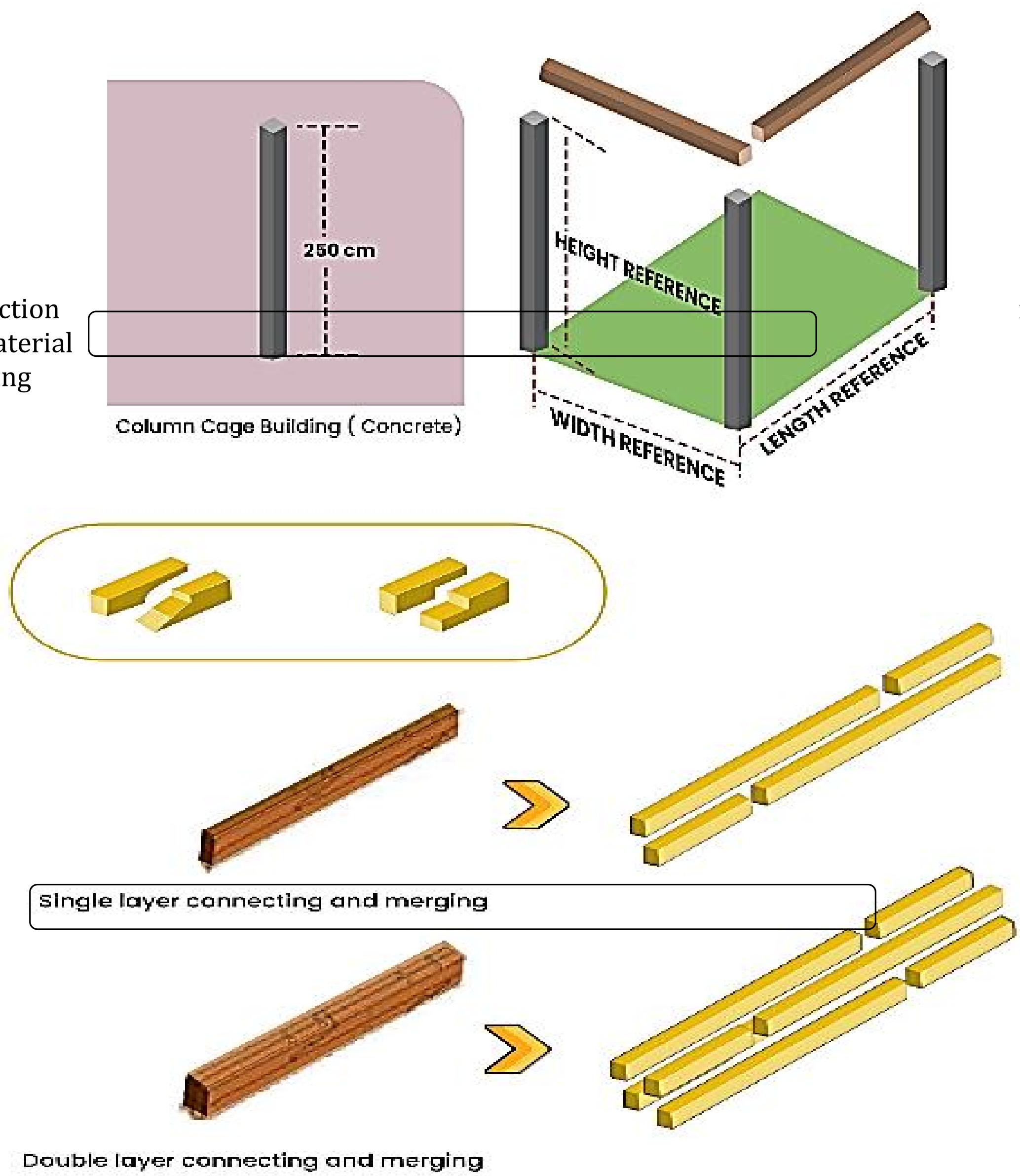
Wutuh-Remuk, Dawa-Cendhak, and Kukuh-Gapuk:Methods of Reusing Building Materials

The victims of the Bantul earthquake perceived the building ruins as locally available materials that were produced due to a natural disaster. Therefore, they needed to develop methods for characterizing the ruins with respect to their form, size, and functionality. The locals preferred to use their own knowledge and terminology to understand and convey their understanding to others. The wutuh-remuk method was used to describe the shape and size of the ruin with respect to its original form, while the dawa-cendhak method described the state of the material based on its length. The locals used these methods to produce materials for construction, including functional, structural, and architectural materials.

"Wutuh-remuk" is used to describe the shape and size of the ruins in relation to their original form. This method produces materials with the same dimensions as the original, without any processing techniques. The material is reused by directly installing it at the desired location. "Dawa-cendhak" describes the state of the material based on its length. If the length is the same or nearly the same as the original length, it is called "dawa." If there is any change in length, it can be described using "cendhak," specifically if the length is less than half the original length. "Dawa-cendhak" methods produce materials different from their original form by deploying material processing techniques like cutting, splicing, and merging to produce larger and longer materials ("gedhe-dawane"). After knowing the shape and size of the material, it is important to understand its strength. As the material is from a building ruin, it will have reduced strength compared to its original strength. Therefore, it is important to understand the use of such materials in providing structural support to new homes being constructed using the ruins. The rafter ("usuk") is one of the building materials that plays a strong role in not only the formation and size of the new larger bars but also in the formation of additional roofing ("empyak"). The "usuk" determines the width of the additional roofing as an extension of the main roof. This highlights the locals' understanding of the importance of connections in the construction process. "Kukuh-gapuk" produces materials as the main structural components through material processing by either eliminating or reducing the "gapuk" portion to produce "cendhek-dhuwure" (high-low strength materials). "Kukuh" describes the state of the material that has a strength nearly the same as its original strength, while "gapuk" describes the state wherein material strength has considerably reduced from its original strength. All these rules aided the locals in obtaining construction-ready materials after certain or no modifications based on the state of the materials used. A summary of these methods is presented in Figure 2.5 and Table 2.3.

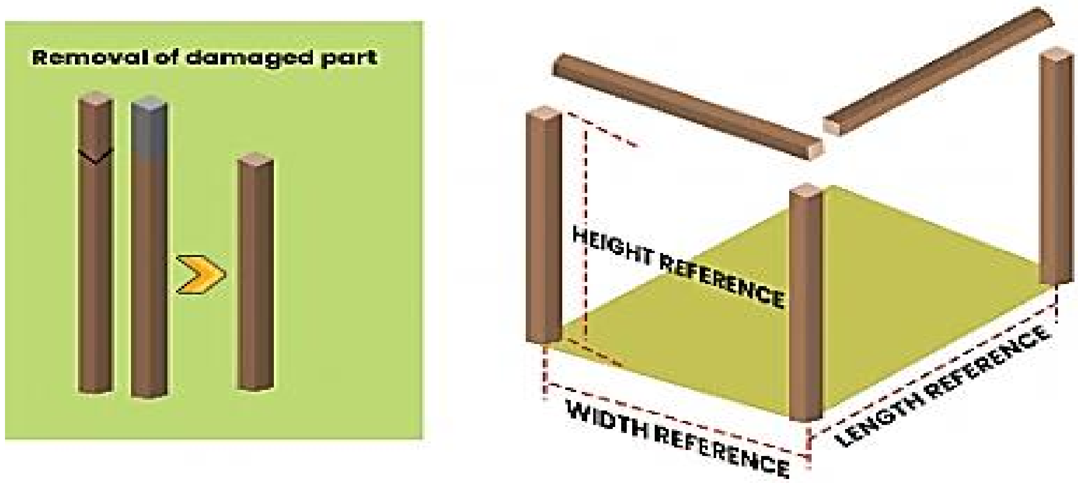
Post-earthquake construction was preferably done on the old building site to have a clear idea of the ratio of new and old building areas. A variety of building shapes in terms of shape, height, and extent were produced by considering the type of building materials, their functions, and the building types. The simple or "straightforward" floor plan and construction using post-earthquake construction materials reflect the architectural work of locals in creating earthquake-resistant building structures. The column height of 2.00-2.25m reduces the shaking level of the building. In addition, the wooden bars along the width and length of the building are arranged using minimal connections, reducing the susceptibility of the buildings to shearing during earthquakes. The new buildings in Bantul were quite different and smaller than the pre-earthquake buildings due to the structural components, namely saka (column), blandar (latai beam), and pengeret (transverse beam), as well as the reduction in the building site area. This reduction was due to the fact that the rubble was not used in the post-earthquake construction.

Construction whole material building (a)



formed from from a cage

Construction is formed by means of joining and merging wooden blocks
(b)



Construction formed from building material ruins using a length-reduction process
(c)

Figure 2.5. Construction practices: (a) wutuh-remuk (b) dawa-cendhak (c) kukuh-gapuk

Table 2.3. Methods of reusing the building materials for construction

Method	Material	Use	Processing	Practicality
Wutuh-remuk	Concrete column cages (*kendhang*)	Produces material as a main structural component, as a reference for the height of the building	Installed in the desired position without processing	Concrete columns in cow pen buildings were used to replace wooden residential buildings
	Wooden plank walls (Gebyok)	Produces supporting components to produce the flexible structure	Installed in the desired position without processing	Used along with concrete columns to provide width reference for walls
Dawa-cendhak	Bars rafter (*usuk*)	Produces material larger and longer (*gedhe-dawane*)	Cutting, splicing, and merging according to desired dimensions of length	Construction is done in one- or two layers using bolts and is easier as highly skilled labor is not required
Kukuh-gapuk	Wooden columns	Produces material as the main component for reference of high-low (*cendhek-dhuwure*) of the building	Cutting of obsolete parts and installation as per the desired position	Reusing wood for columns but with shorter lengths, thereby new buildings had a column height of 2.5

				m against 3-4 m

Niteni, Niroake, Nambahake, and Nemoake: Methods for Independent Reconstruction

The post-earthquake construction was not specifically guided by the ideas of builders, but rather by the specific materials available for construction. The form and availability of building ruins used in construction dictated the form of the new buildings. In Bantul, while people decided to use post-earthquake rubble as their construction material, specific skills were needed to incorporate its use effectively. Rakhman (2012) suggests that a community's ability to address such circumstances lies with niteni (attention), niroake (mimic), and nambahake (add). Niteni is the outward manifestation of the capacity to pay attention and acquire an understanding of a phenomenon in order to map the potential of a material for reuse in construction based on one's knowledge. On the other hand, niroake and nambahake have more advanced reuse capabilities as they allow for the adaptation and reapplication of previous information to make changes that fit new situations. This practice in Bantul describes the locals' understanding of the material ruins and their reuse. Their knowledge was not limited to understanding the material or mimicking its behavior; they also had the idea of building creative works (nemoake) using the knowledge gained during post-earthquake housing construction.

Urip Sakmadya and Nrimaing Pandum: Construction Models for Sustainable Lifestyle

These practices imply the evolving techniques of the earthquake-affected locals in Bantul, which should serve as an inspiration for the role of assistance any community can provide in mitigating the suffering after a disaster.

It is imperative to understand the principles of "simple living" and "accepting reality" so that one can feel content with post-earthquake dwelling places. The people of Bantul constructed their homes using the post-earthquake ruins, which resulted in a lower ratio of new building areas compared to the old ones. However, they managed and accepted this construction wholeheartedly, which made the practice of "architecture without architects" a great success in itself. The term urip sakmadya is used to describe the unpretentious life. This construction model is based on the principle of using simple patterns along with connected and combined techniques. The concept of accepting facts has been called nirmaing pandum, which uses the concept of makeshift materials. Both of these methods are based on the adjustment of the ruined building materials to be used in the construction of building fields.

The comparison between the site area and the building area post-earthquake is shown in Figure 2.6. The figure suggests that the new buildings constructed using building ruins can cover 30-50 percent of the original plan area of the buildings. The occupancy of the new houses is only one-third of their pre-earthquake houses. This scenario highlights the level of acceptability needed in the community for such construction after an earthquake. The Bantul community not only self-constructed their homes using building ruins but also displayed a great level of acceptance and comfort towards their new dwelling places because they had experienced the situation of being homeless after the earthquake. The new buildings constructed after the earthquake provide an example of easy procurement of construction materials, simple construction, and strong motivation to understand the sustainability of potential building materials. This is what is required in any community to facilitate sustainable construction after any disaster.

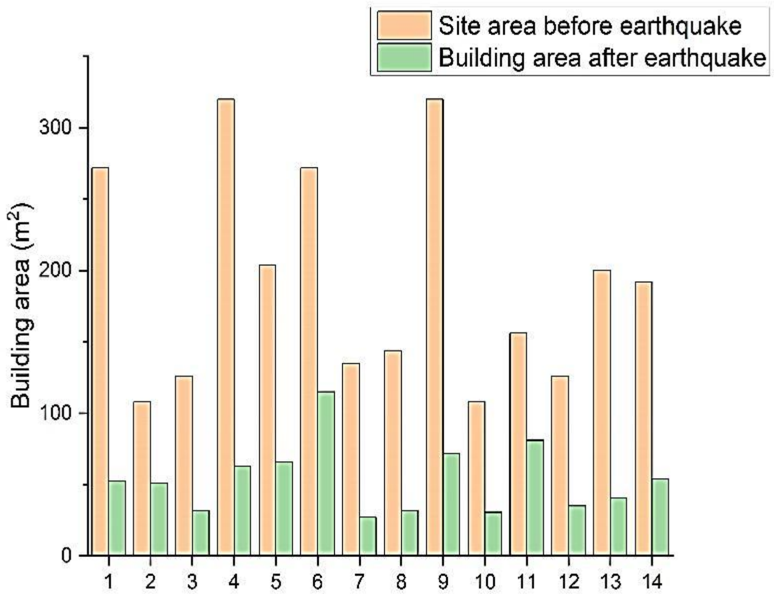


Figure 2.6. Comparison of site area with building area after the earthquake (Surveys & Measurements, 2013 & 2015)

Conclusion

Bantul, a small district in the Yogyakarta province of Indonesia, is known to be the most disaster-prone and poverty-stricken area with limited capability to manage a disaster. The victims of the 2006 earthquake in Bantul were left homeless but not hopeless after the earthquake. They realized, and most importantly accepted, the fact that their homes were destroyed but were grateful for the availability of building waste after the earthquake. This chapter presents an informative case study on Bantul, Indonesia, highlighting the uses of construction waste (earthquake ruins) and potential building materials in post-earthquake housing reconstruction. The victims portray a good example of "Community-Based" post-earthquake housing reconstruction, in which they independently performed the residential redevelopment after the earthquake using their designs and practices while incorporating the use of earthquake debris to its full potential. The dominance of wood-based construction in Bantul provided adequate resilience and flexibility to the structure, while its collapse still gave an opportunity for its reuse in post-earthquake housing construction. The people of Bantul advantageously used this fact to build their homes after the earthquake even before the involvement of the local government. After the recovery, Bantul was reimagined as a well-planned area with a targeted development strategy. The Bantul community not only self-constructed their homes using building ruins but also displayed a great level of acceptance and comfort towards their new dwelling places, even though the building area was reduced by 50-70% with respect to the earlier plan area. This depicts the acceptance of principles like "simple living" and "accepting the reality". The new structures built following the earthquake serve as an example of straightforward material procurement, straightforward construction, and a strong drive to comprehend the sustainability of possible building material ruins. This is necessary for every community to permit disaster-recovery construction.

Conflict of Interest Statement

The author declares that there is no conflict of interest.

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