Advances in Engineering Research, volume 156

18th International Conference on Sustainable Environment and Architecture (SENVAR 2018)

Spontaneous Innovation in the Reuse of Post-Earthquake's Buildings Ruins as Sustainable Building's Construction Models

Kahar Sunoko
Department of Architecture
Universitas Sebelas Maret
Surakarta
kaharsunokouns@gmail.com

Amin Sumadyo
Department of Architecture
Universitas Sebelas Maret
Surakarta
amiensumadyo@staff.uns.ac.id

Hari Yuliarso
Department of Architecture
Universitas Sebelas Maret
Surakarta
hari.yuliarso@yahoo.com

Abstract— Some earthquake victims carried out housing reconstruction activities independently before the government or other parties provided reconstruction assistance. They are reusing the ruined building materials to make post-earthquake building construction. The building survived and became the main building they inhabit until now after a decade has passed. The form of construction that is established is interesting to be studied more deeply as a model of sustainable building construction. The building has very typical construction patterns based on the types of material availability, building skills, and funds availability. The result of building construction is a spontaneous innovation that can be developed for the construction model in the sustainable building development.

Keywords— reconstruction, post-earthquake, reuse, ruins, construction.

I. Introduction

The portrayal of post-earthquake conditions is the availability of building ruins. Setyonugroho (2013)[1] and Andriani (2013)[2] illustrate that earthquakes cause damage marked by the ruins of buildings that are widely found in the earthquake location. The description of the ruins shows the characteristics of the debris namely the type of the remaining materials and the position of the ruins.

The description of post-earthquake conditions in the practice of building materials utilization was also stated by Marcella (2011)[3] that the community chose to collect debris of their building materials, select and reuse them. Reuse of existing building materials has problems in terms of availability and strength.

In the aftermath of the 2006 Bantul-Yogyakarta earthquake (Sunoko, 2017)[4], there was a peculiarity in each building resulting from self-reconstruction. Diversity phenomena occur in each house related to the availability and use of debris material, construction techniques, as well as the ideas and shape of the building.

This phenomenon is in line with Leuken's (2013)[5] opinion that the process of creating a residential or architectural design involves the user in the design process; the user knows their own life habits best. So that the role of victims in carrying out reconstruction in the aftermath of the earthquake and its ability to realize building construction, and the variations in construction produced are interesting things to study. The aim of this conducted research is to get an explanation of the building construction models produced,

The use of ruined building materials is related to the limited quantity of natural resources. Hence, it needs efforts to conserve natural resources and if necessary, use the used building materials that are still feasible, without reducing aspects of building strength. Until now there is not much information about the potential of used building materials in the construction projects.

Ervianto (2012) [6] explained that from building blocks produced building materials that can be reused and recycled such as wood, concrete, red brick, and metal reaches 75% of the total waste. Reuse of unloading material by applying the 3R principle: Reduce, Reuse, Recycle. This research focuses more on reuse, rather than reduce or recycle, which is to reuse rubble building materials, not reduce the use or recycle the ruined building materials. Reuse means maximizing use, not reduction and not recycling.

Reuse material is the use of construction materials resulting from deconstruction or demolition followed by recycling. This category is like the building material in the case of this research that the building has collapsed due to the earthquake. In the case of ruined building materials due to the earthquake, Syukur (2008) [7] stated that the typology of reuse of building materials is based on the components that form components and the function of building materials used in building materials. Reuse of building component materials is divided into two, they are structural components and architectural components. In practice, the architectural component has more potential than building structure components, this is due to the ease of separating architectural components from other parts of the building.

II. Method

This research was conducted in the Mulyodadi and Canden regions, Bantul, Yogyakarta following up on the findings from the previous research (Sunoko, 2017) that the reconstruction practices carried out by victims independently by reusing building materials from the ruins of their own homes. This study focuses on construction products resulting from the reuse of ruined building materials.

This research uses descriptive research method with a quantitative-qualitative approach. Data collection is done through quantitative observation and measurement, as well as interviews. Measurements are made within the scope of the construction model resulting from the reuse of ruined building materials. Furthermore, descriptive deepening is done by interviewing the actors of reconstruction. Field data exploration is carried out with the human element as the main tool for recording data as well as analysis in this study.

III. RESULTS AND DISCUSSION

The condition of the ruined building materials shows that some of the building materials were damaged which resulted in size changes. Building materials in the post-earthquake context are available in dimensions and characters that are definitely different from similar building materials that are available during normal conditions.

The reuse of ruined building materials to rebuild homes after the earthquake indicates several typologies. First, the use of building materials of different types of buildings and types of building materials but used in the same function. Second, the use of building materials of the same type of building and type of building materials but on different functions. Third, the use of building materials from the type of building, the type of building materials and the same function.

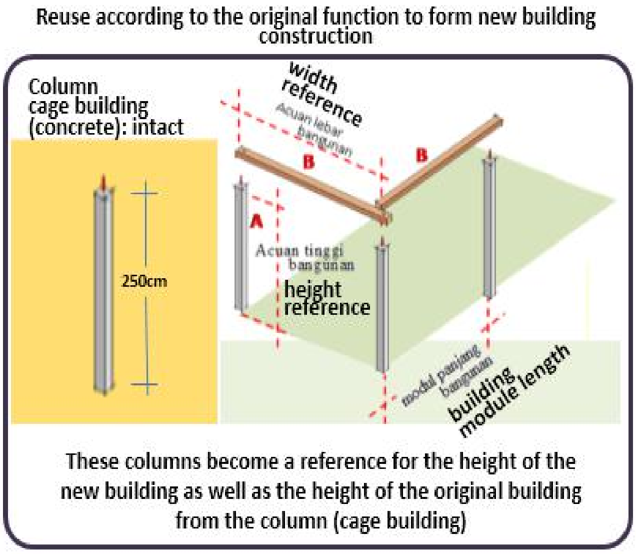

Figure 1. Construction that is formed from whole material from a cage building

In the first type, building materials in the form of concrete columns in a cow pen building are used to replace the use of wooden buildings that are usually used in residential buildings. It is used in a fixed position or the same function as a column. Cow cages are owned by most villagers in the Mulyodadi village. Concrete column construction in the cow pen does not collapse during an earthquake, thus inspiring earthquake victims to use it in the manufacturing of houses after the earthquake.

The second type, the use of materials of the same type of building and type of building material but with different functions. In the absence of wood dimensions suitable for functions as horses, *gording*, and *nok*, a *usuk* wood is modified for this function.

The resulting construction is in the form of a connection or a combination of *usuk* wood which has dimensions smaller than it. The construction of this construction is done in one- or two-layers using bolts. This method is considered the easiest for them, because it does not require highly skilled work.

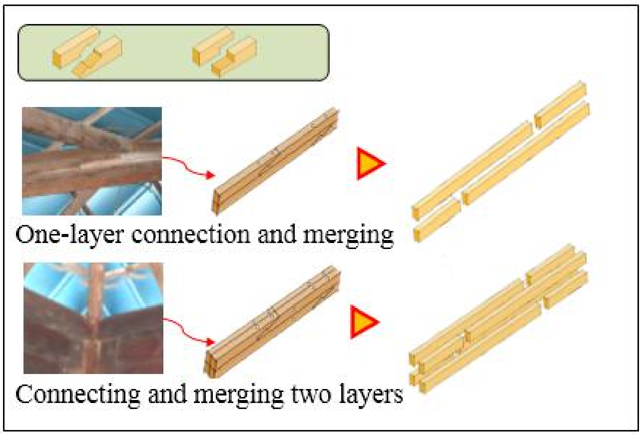

Figure 2. Establishment of wood construction by means of joining and merging

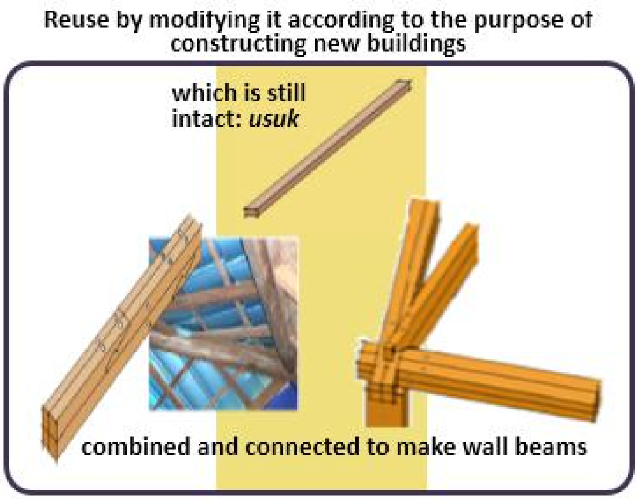

Figure 3. Combination of smaller dimension rods to form a larger dimension rod construction

The third type is the type of building, the type of materials and the same function. The use of wood is in accordance with its original function but with a change in the length of the stem because it broke when it collapsed. Reusing wood for column functions, but the column length is shorter than the previous size. The new building has a column height of + 2.5 m, while the previous building is 3 m - 4 m. (see figure.4)

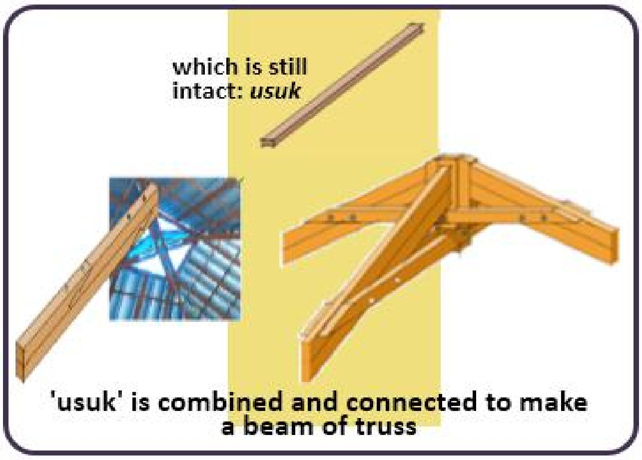

Figure 4. Combining shorter dimension rods to form a longer rod construction

The post-earthquake building was rebuilt on the old building site so that it was evident that the ratio of the new building area to the previous building. Victims have rebuilt the post-earthquake shelter. The types of building materials, types of buildings, and the function of building materials form a variety of building shapes after the earthquake in terms of height, extent, and shape.

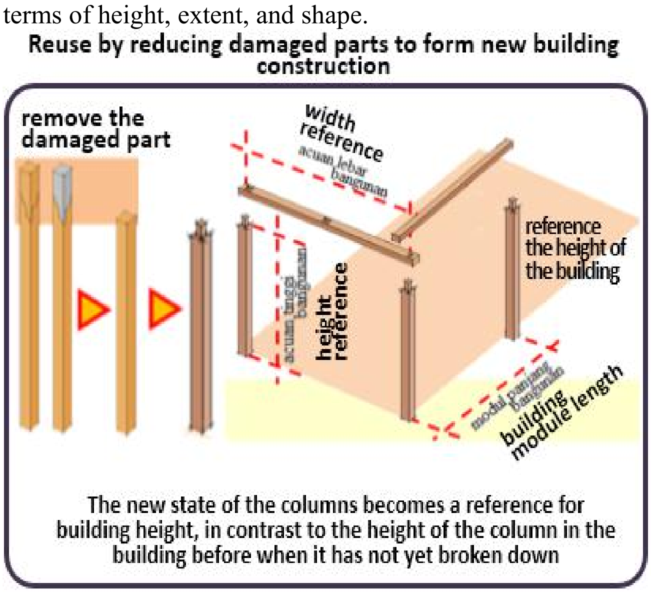

Figure 5. Construction formed from building materials collapses with a length reduction process.

The architectural work of earthquake victims is reflected in the configuration (floor plan) and the form that is "straightforward" or simple. The simplicity of form and construction resulting from the reuse of ruined building materials is another option from the completion of earthquake resistant building structures.

The height of the typical structural column (2.00 - 2.25m) that is produced makes the level of effectiveness of the reduction to the shake caused by the earthquake become high. The logs that form the width and length of the building are arranged by minimizing the connection, thus reducing the point susceptible to the shear force caused by earthquake shaking.

The simplicity of the construction constructed from the ruined building materials reflects a very different structure and building module compared to the structure and shape of local building modules in Bantul. This situation is formed by building materials that form the main structural components, namely *saka* (column), *pengeret* (transverse beam), and *blandar* (*latai* beam) derived from the application of *kukuh* rules, the existence of wood parts that must be reduced due to damage. Furthermore, the development of the shape of the core building structure is very dependent on the availability of "short-length" existing *usuk*. These conditions affect the extent of development of the main modules that have been formed previously.

The above conditions form the building area after the earthquake, which is smaller than the pre-earthquake building site area. This was backed up by the construction of rubble which could not be reused as construction material, causing a reduction in the number of building materials forming buildings after the earthquake.

The form of the ruins shows its role in determining the extent of the new buildings that will be formed. It is understood that the ratio of the building area after the earthquake to the site area of the artifacts is affected by the availability of ruined building materials. However, no matter how much ruined building material is available, it is based on the principle of living a "simple life" and "accepting the reality" that makes them able to form new construction structures, new residential buildings after the earthquake.

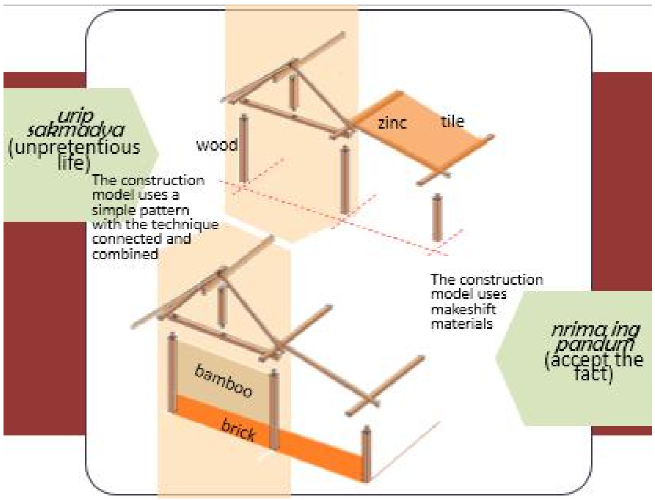

Figure 6. Development of construction of building fields adjusting the availability of ruined building materials.

The dominance of the intact ruins of building materials gives a higher contribution to the area of the building produced so that the opposite condition will occur if the condition of the building materials is very small: it will make the area of the building produced smaller.

The state of brick building materials has a high level of damage, so the role of its use as a building construction material is not high. The collapse of the building due to the earthquake resulted in the building material being destroyed. The same is true with bamboo, although its use is not high but because of the age of the material results in its destruction. More building ruins are dominated by wood building materials.

Victims prioritize the use of wood with consideration of the level of ease and practicality in the process. Reuse of wood does not require additional materials, the use of nails as a connecting device is enough to use old nails from the remnants that have been trimmed. Woodworking can be carried out with simple tools. They use more equipment for cutting purposes. The victims did it with a saw, even when the availability of saws and woodworking equipment was inadequate, they were enough to replace it with agricultural equipment, namely machetes and sickles.

Table 1: The form of ruins of buildings and building area after the earthquake

No	Comparison site area with building area after an earthquake		
	The Site (m²)	Building after an earthquake (m²),(%)	
1	272	52.50	**19.30%**
2	108	51.00	**47.22%**
3	126	32.00	**25.39%**
4	320	63.00	**19.69%**
5	204	66.00	**32.35%**
6	272	115.00	**42.28%**
7	135	27.00	**20.00%**
8	144	32.00	**22.22%**
9	320	72.00	**22.50%**
10	108	30.50	**28.24%**
11	156	81.00	**51.92%**
12	126	35.00	**26.98%**
13	200	40.50	**20.25%**
	191.62	53.65	**27.61%**

The ability needed is cutting and connecting. The splicing technique refers to the habit of connecting wood commonly carried out by local artisans.

Usuk (rafter) is a building material in ruins that plays a very strong role. In addition to the formation and size of new and larger bar construction materials, it also plays a role in determining the formation of additional roofing or *empyak* as an extension of the main roof construct. The width of the *empyak* is determined by the availability of *usuk*. This is shaped by the understanding and conviction of the victim that the perfection of the construction power is useless by avoiding the connection.

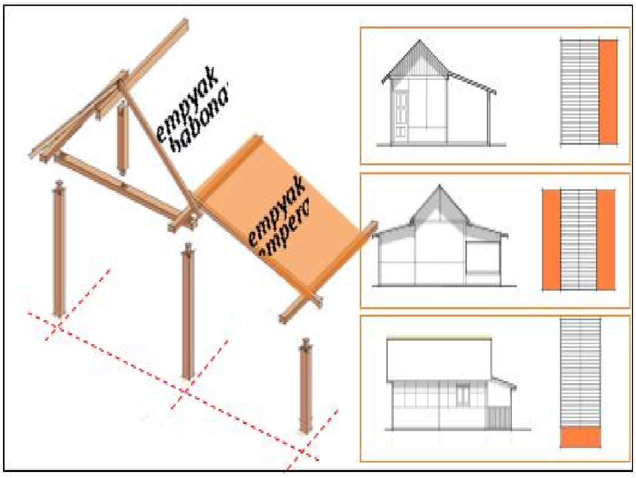

Figure 7. *Empel émpéran* (additional roof area) and type of addition

The availability of building materials for wood ruins can contribute to the formation of new buildings covering an area of 30 to 50 percent of the area of pre-earthquake building footprints. While the limitation of the condition of ruined building materials is still capable of producing new buildings covering 19 to 28 percent of the area of pre-earthquake building footprints. This situation actually shows the ability of victims to carry out reconstruction as well as the attitude of acceptability towards the form of new housing after the earthquake which was generated from their own efforts by reusing the maximum building materials of the ruins.

The resulting percentage of the area reached an average of 27.6%, this amount compared to the site area as an illustration of the representation of residential buildings before the earthquake was very different. They occupy a new house after the earthquake, on average only one-third of the size of their house before the earthquake however, no form of a new house is a problem for victims, because they have experienced a more bitter situation of living without a home.

The role of the rubble building material can then be seen from its composition in meeting the needs of building materials in post-earthquake residential construction. The role of ruined building materials in their re-use to realize post-earthquake buildings in Bantul is very dominant, up to an average of 86.47%. This shows a strong link between the process of inventorying debris building materials to the process of their use.

Victims have an optimal tendency in the use of ruined building materials, even up to 100%. (Table 2 and diagram 2). Victims are more oriented to "having a home" so that they do not spend too much time in the tent, they are not oriented towards large house ownership, and they are more realistic about "simple life" as a reflection of the principle of "accepting reality" by making enough building materials without having to bother scrap out of their ability at that time.

Table 2: Use of building materials in ruins and new building materials

No	D (m²)	A (m²)	BR (m²)	BB (m²)	% BR	% BB
1	107.5	57.75	165.25	35	**78.82**	**21.18**
2	120	56.5	176.5	-	**100**	**-**
3	95	35.5	130.5	32	**75.48**	**24.52**
4	141	69.5	210.5	74.7	**64.49**	**35.51**
5	133.	72.5	205.5	35	**83.03**	**16.97**
6	190	126.	316	65	**79.46**	**20.54**
7	60	29.5	89.5	-	**100**	**-**
8	88	35.5	123.5	-	**100**	**-**
9	153	80	233	36	**84.55**	**15.45**
10	68	34	102	-	**100**	**-**
11	108	89.5	197.5	85	**56.96**	**43.04**
12	77.5	38.5	116	-	**100**	**-**
13	78.7	44.5	123.2	-	**100**	**-**
			Rata-rata (%)		**86,47**	**13,53**

Information :
D: Plan A: Roof
BR: Ruins Building Materials
BB: New Building Materials

The contribution of ruined building materials to realize post-earthquake occupancy an average of 27.61% of the pre-earthquake building site area, while the contribution of building materials to the buildings after the earthquake reached an average of 86.47%. Thus, it can be understood that if the use of building materials in ruins reaches an average of 86.47% of the site area, the role of non-ruined building materials in post-earthquake buildings is only 19.53% on average. Thus, the relationship between the form and role of the building materials of the ruins can be traced.

The form and role of non-ruined building materials are influenced by the involvement of family members or relatives outside the village who did not experience a building collapse during the earthquake. These parties carry non-rubble building materials, as they have or which can be cultivated, as a form of solidarity, empathizing with the disaster experienced by the victims. Limited access to new building materials is caused by financial conditions.

Efforts to meet the shortcomings of the main building materials (ruined building materials) are taken by utilizing the trees in the location, namely coconut, jackfruit, and *melinjo* trees, by carrying out the logging process until sawing and cleavage to be made into bars or boards.

The state of the percentage of building area that is generated from the reuse of ruined building materials, if traced back, will be a contribution flow and the role of the ruined building material to the extent of the building produced. This process occurs in a rotating cycle. The process of inventory and use of building materials leaves debris building materials that have not been used at that time, so that deposits of building materials will in time be used for development.

The condition of the new building gives a picture of construction that is quite simple, and it is easy to carry out its procurement. Explanation of materials and construction provides an overview of the spirit and hard will for architecture. Limited availability of materials does not hamper earthquake victims to have new housing. Post-disaster survival is a strong motivation for understanding the sustainability of the potential of building materials.

IV. Conclusion

Post-earthquake Bantul ruins building materials are available on site and reused to realize post-earthquake occupancy dominated by wood building materials.

Wood-based construction has adequate flexibility and resilience to the impact of the earthquake, and its collapse still provides an opportunity to be used again to build new construction in the aftermath of the earthquake independently. So wood provides a good level of sustainability in building design with earthquake disaster response.

Percentage of building area resulting from the reuse of ruined building materials is affected by the condition of the ruined building materials in terms of size and dimensions. Its feasibility to form a construction has an impact on the height and width of a typical building.

References

[1].Andriani, 2013, *Pemanfaatan Reruntuhan Bangunan Pasca Gempa Untuk Memperbaiki Tanah Lempung Sebagai Subgrade Jalan*, Konferensi Nasional Teknik Sipil 7 (Konteks 7), Surakarta.

[2].Leuken, 2013, *Participation of The User in The Design Process Regarding to Shelter in The Developing World* , Delft University of Technology Faculty of Architecture

[3] Marcella, B, P., 2011, *Perilaku Masyarakat Dalam Memilih Pemanfaatan Ulang Dan Daur Ulang Bahan Bangunan Pasca Gempa Bumi*, Jurnal Arsitektur KOMPOSISI , IX (1) April 2011.

[4].Setyonugroho, G, A., 2013, *Pembangunan Berkelanjutan Dalam Rekonstruksi Rumah Pasca Gempa Yogyakarta 2006 Di Dusun Ngibikan*, Bantul, Jurnal Arsitektur Komposisi, Volume 10, Nomor 3, April 2013.

[5].Sunoko, Kahar., 2017, *3S and 4N Concept as Independence Being Victims in Post-Earthquake Reconstruction*, The International Journal of Social Sciences and Humanities Invention 4(3): 3356-3360, 2017

[6]. Ervianto, 2012, Material Reuse Study in the Concept of Sustainable Construction in Indonesia, Journal of Civil Engineering Volume 12, No. 1, October 1, 2012.

[7]. Syukur, La Ode Abdul, 2008, Study of the application of reuse of building materials in house reconstruction after the earthquake: Case study Gunung Kelir Hamlet, Pleret Village, Pleret District, Bantul Regency, Yogyakarta Special Region. Dissertation, UGM, Yogyakata