Efficiency of House-Walls Construction Using Building Ruins

Andi Prasetiyo Wibowo
Architecture Department, Faculty of Engineering, Universitas Atma Jaya Yogyakarta

e-mail : andiprasetiyo@staff.uajy.ac.id

Abstract. The stage of reconstruction of houses collapsed and damaged by the quake could amount to hundreds of thousands of homes and had to be rebuilt at almost the same time. This will result in a large need for building materials, thus affecting the price of building materials, as well as the demand of builders / construction workers. A major earthquake, such as the one that occurred in Yogyakarta, on May 27, 2006, has resulted in hundreds of thousands of homes severely damaged and collapsed, resulting in a large number of ruins of building materials in the form of masonry walls. The existence of waste material collapses, is a huge potential when reused as a building material through appropriate recycling technology, which can answer two problems at once that meet the needs of building materials and on the other hand can clean up the waste collapse of the building. The construction of walls from wall-crumbling powder (recycled material) is more efficient and effective than conventional wall-making systems when used for mass construction (more than 20 homes) at the same time.

1. Introduction
Green Technology is now one of the most talked-about issues around the world. Many parties try to develop it in various fields including in the construction world. The purpose of this concept is to answer the environmental problems that are increasingly leading to the destruction, which among others is the result of massive exploitation of natural resources on earth for construction, such as sand, stone, gravel, clay for brick making etc.

On the other hand, the use of very large amounts of construction in the world, for example: the construction of houses, buildings, bridges, dams will affect in a continual taking building material from nature that can lead to extinction of those material. This will disrupt the balance of the environment; the environment becomes damaged, which will ultimately harm human beings themselves.

Furthermore, we need an alternative way as a breakthrough step in preventing the occurrence of environmental damage is getting worse and bigger. Currently known as a sustainable development concept which offers a balance between the preservation of nature with the fulfillment of human needs that are growing in the future. According to World Commission on Environment and Development [1] in 1987, Sustainable is "meeting the needs of the present without harming future generations to meet their needs." There are three things that the goal of this concept is to achieve:
1. Minimize material and energy consumption.
2. Prevent negative effects on the carrying capacity of the environment and the environment itself.
3. Meet human needs.

Sustainable buildings are buildings that use methods and building materials that highly prioritize environmental quality, economic vitality and social benefits through the design of development,
building operations, maintenance and deconstruction of the built environment. Standing buildings that use technology today are responsible for consuming 40% of the flow of energy and materials from the earth (Roodman & Lenssen[2]), so the effects of building these buildings are enormous for nature.

The recyclable material referred to in this paper is derived from the remains of unused building debris which is then processed in such a way that it can be reused for development. However, there are some things to consider before applying this concept, because sometimes the use of a technology if not properly studied, it will actually bring bad impact even worse than previous technology, among others, the increased energy needed to collect and process the material, or it turns out there is no environmentally friendly technology that can process the building materials, or even the fact that building materials derived from nature require energy and costs much smaller than the existing recycled materials. It is therefore necessary to select the correct and appropriate technology in the processing of recycled materials so that it can be reused for development.

One application of the use of the concept of recycled materials, it would be very appropriate when used in times of natural disasters that are currently often experienced, especially earthquakes, i.e. at the stage of reconstruction of houses collapsed and damaged by the earthquake, whose number can reach hundreds of thousands of homes, which had to be rebuilt at almost the same time, resulting in a high demand for the need for building materials, affecting the skyrocketing prices of construction materials, as well as the demand for builders / construction workers.

This can be seen, among others, on the occurrence of a major earthquake in Yogyakarta, on May 27, 2006 which has resulted in hundreds of thousands of homes suffered heavy damage and collapsed, resulting in waste of a large number of collapsed building materials in the form of a wall of masonry as shown in figure 1.

Figure 1. Waste of the wall ruins that are considered unusable. (Satyarno[3])

The local government of Yogyakarta dumped out the building ruins not on the appropriate land, some of which even dumped into places or productive land such as rice fields, due to limited costs. (Satyarno[3]; Satyarno[4]; Tjokrodimaljo[5]).

The existence of building ruins, is a huge potential when reused as a building material through appropriate recycling process, which can answer two problems at once that meet the needs of building materials and on the other hand can clean up the waste collapse of the building.

2. Research Methodology

The method of writing this paper is done by collecting secondary data through literature study and document study that is data collection based on the results of research related to the utilization and use of materials used building materials, especially waste building debris.

The data obtained will be analyzed qualitatively i.e. the analysis done by understanding and assembling data that has been collected and arranged systematically then drawn conclusion.
3. Analysis And Discussion
Waste disposal materials (wall ruins) can be processed by manual (human power) or using a crushing machine (Satyarno\textsuperscript{[3]}). The crushing machine of the wall ruins as shown in Figure 2. In general, waste crushing machine works like stone crusher consisting of three parts, namely the frame of the cradle equipped with wheels for the machine to be easily transferred, the chamber/crushing room and a propulsion engine in the form of a diesel engine. Inside the chamber there are spinning blades to crush the waste of the wall ruins that poured into.

![Figure 2. The ruins of the building walls were crushed using a machine. (Satyarno\textsuperscript{[3]})](image)

From the analysis of grain size analysis or gradation of fine aggregate showed that the powder of the wall ruins was in zone II (somewhat rough) with fine modulus of grain (MOG) of 2.61 where sand generally has MOG value between 1.5 to 3.8. The weight of the powder unit from the wall ruins is 1,360 gr / cm\(^3\) while the sand is 1,656 gr / cm\(^3\). From these results, the weight of powder units from the ruins of the wall is smaller than the sand but still includes the normal fine aggregate. Examination of specific gravity in the state of SSD (Saturated Surface Dry) obtained a value of 2,315 for powder from wall ruins and 2,669 for sand. Specific gravity in the absolute dry state of 2,082 for powder from wall ruins and 2,594 for sand. From these results it can be seen that the powder density of the wall ruins is smaller than the sand but still includes the normal fine aggregate.

Utilization of the powder of the ruins of the wall as a building material based on the results of previous research (Satyarno\textsuperscript{[3]}; Satyarno\textsuperscript{[4]}), it is known that the powder ruins of the wall have higher absorption than natural sand, because according to the examination of chemical content in powder ruins wall has silica although the value is only 21.458\%, so it is likely to have pozzolan properties. Thus a wall collapse which is then processed into a powder can be used instead of natural sand. According to the results of the research (Satyarno\textsuperscript{[3]}; Satyarno\textsuperscript{[4]}), powder wall debris when used as a substitute for sand and used as fine aggregate on the mortar mixture obtained the result that the mortar weight per cubic meter is smaller than that of sand mortar as fine aggregate.

![Figure 3. Portions of the mixture and compressive strength of mortar using powder wall debris (Satyarno\textsuperscript{[3]})](image)
From the test results (figures above), the compressive strength is obtained depending on the ratio of cement volume and powder depending on the portion of water used and it is recommended to use the ratio of cement volume: powder between 1: 4 to 1: 6 or can be used on average mixture of 1 cement: 1.25 water: 5 powder. The maximum gain strength can get 10 MPa.

3.1. Field Implementation (onsite)
The new wall-making system at the site uses reinforced concrete using a special mold instead of masonry. The material used to make the wall is a mortar with a mixture of water, cement, powder wall debris and inside the walls are fed a diameter of 6 mm diameter with a distance of about 40 cm.

![Image](Figure 4. The process of making the walls with cast in place method (Satyarno[3]))

Price Comparison / Cost of Making Wall between using Special Method and conventional method, either based on SNI Analyst, and BOW Analyst. The advantages of financing the construction of wall work as described above, can be seen comparing the calculation as follows:

| No | Method | Volume | Unit price (Rp) | cost (Rp) |
|----|--------|--------|----------------|-----------|
| 1  | Cast in place | | | |
| a. 1 m² Crushing Brick Waste | 80.85 | 2,657.31 | 214,843.51 |
| b. 1 m² wall casting | 80.85 | 57,406.21 | 4,641,292.08 |
| c. 1 m² mold installation | 40.4 | 2,700.00 | 109,080.00 |
| **Total cost** | | | **4,965,215.59** |
| 2  | Conventional, SNI Method | | | |
| a. 1 m² Brick Installation 1/2 stone | 80.85 | 48,490.00 | 3,920,416.50 |
| b. 1 m² Plastering | 161.7 | 16,215.00 | 2,621,965.50 |
| c. 1 m² Edging | 116.8 | 3,458.00 | 403,894.40 |
| **Total cost** | | | **6,946,276.40** |
| 3  | Conventional, BOW Method | | | |
| a. 1 m² Brick Installation 1/2 stone | 80.85 | 69,064.03 | 5,583,826.83 |
| b. 1 m² Plastering | 161.7 | 24,725.20 | 3,998,064.84 |
| c. 1 m² Edging | 116.8 | 4,010.30 | 468,403.04 |
| **Total cost** | | | **10,050,294.71** |
From the table above it can be seen that the cost of wall work by using wall collapsing powder material is cheaper than cheaper wall work with conventional brick material with SNI and BOW methods. It should be noted, however, that the construction of walls with wall-ruins powder, with cast in place method requires additional tools such as cruher machine, mould, equipment, etc.

Table 2. The equipment for cast in place method (Cahyono, Eko Puji[6])

| No | Tool type  | Unit price (Rp)   | amount | cost (Rp)  |
|----|------------|-------------------|--------|------------|
| 1  | Stone Crusher | 20.000.000,00   | 1 unit | 20.000.000,00 |
| 2  | Mould      | 1.719.550,00     | 11 set | 18.915.050,00 |
| 3  | Buffer     | 170.000,00       | 22 set | 3.740.000,00  |
|    |            |                   |        | **Total cost** | **42.655.050,00** |

Procurement of equipment mentioned above, indirectly makes the unit price index for making the wall printing in place becomes more expensive. But the cost of procurement will be cheaper if it is charged to many homes. In other words, the more houses built, the price of the printed wall unit in place will be cheaper, near the price according to table 2. For more clearly can be seen in Figure 5 below.

![Figure 5](image)

Figure 5. The Comparison of house wall building cost-estimate per m², using cast in place method, SNI Analyzing Calculations, and BOW Analyzer Calculations (Cahyono, Eko Puji[6])

The cost of wall construction with cast in place method will be proportional to the work of the masonry pairs using the BOW method on the construction of the 7th house unit (± 10 million / m²), whereas if compared to the SNI will experience the equivalence of the price on the construction of the 19th house unit (± 7 million / m²), for more and more houses are built, the per-m² price of the printed house walls will be cheaper.

In addition to cost factors, it turns out that cast in place method also has a predominantly in terms of time and work efficiency. This can be seen from the comparison table below.

Table 3. Comparison of the performance of cast in place methods with conventional methods (Yunus Anis, Mochamma[7])

| Description        | Cast in place method | Conventional method |
|--------------------|----------------------|---------------------|
| Area of building   | 300 m²               | 120 m²              |
| Work duration      | 70 days              | 60 days             |
| Manpower           | 6 – 8 workers        | 14 – 18 workers     |
4. Conclusions
Recycled building materials from wall ruins can be used in powder form as a natural sand (fine aggregate) through crushing/recycling process. Mortar made from wall-ruins powder is suitable for use as a simple wall-construction material especially in mass construction. Fine aggregate from wall-ruins powder (through recycling material process) is more efficient and effective than natural sand if used for mass construction (more than 20 houses) at the same time. Work methods with cast on-site method also have an advantage in terms of time and work efficiency.

References
[1] World Commission on Environment and Development 1987 Our Common Future (Oxford University Press)
[2] Roodman, D.M. & Lenssen, M 1995 A Building Revolution: How Ecology and Health Concerns Are Transforming Construction (Worldwatch Paper #124)
[3] Satyarno, I. 2007 Pembuatan Kembali Rumah Tembok yang Runtuh Pasca Gempa dengan Sistem Daur Ulang Cetak di Tempat (Seminar Nasional Teknologi Tepat Guna Penanganan Sarana Presarana di Indonesia)
[4] Satyarno, I. 2006 Recycling Procedure of Brick Masonry Wall Rubble (Proc. of the International Seminar and Symposium, Earthquake Engineering and Infrastructure & Building Retrofitting, August 28th 2006), Graduate School for Infrastructure Management Gadjah Mada University in Collaboration with Research Center For Engineering Science Gadjah Mada University, Yogyakarta.
[5] Tjokrodimulyo, K. 2007 Teknologi Beton (Biro Penerbit KMTS Fakultas Teknik Universitas Gadjah Mada)
[6] Puji Cahyono, Eko 2007, Perbandingan Rencana Anggaran Biaya Bangunan Konvensional dan Bangunan Cetak di Tempat dengan Analisa Metode SNI 2002 (Tugas Akhir JTSL FT UGM, Yogyakarta)
[7] Yunus Anis, Mochammad 2007 Perbandingan Pelaksanaan Pembangunan Rumah Metode Cetak di Tempat dengan Pembangunan Rumah Konvensional (Tugas Akhir JTSL FT UGM, Yogyakarta)