Study on prefabrication method for housing in Indonesia by utilization undegradable waste for building material

Zuraida, Siswanti
Graduate School of Environmental Engineering, The University of Kitakyushu : Doctoral Student

Dewancker, Bart
Department of Architecture, The University of Kitakyushu

Romi Bramantyo Margono
Graduate School of Environmental Engineering, The University of Kitakyushu : Doctoral Student

Muhammad Arief Irfan
Department of Architecture, Faculty of Engineering and Design, Institut Teknologi Sains Bandung

https://doi.org/10.5109/5909090

出版情報：Proceedings of International Exchange and Innovation Conference on Engineering & Sciences (IEICES). 8, pp.189-195, 2022-10-20. Interdisciplinary Graduate School of Engineering Sciences, Kyushu University
バージョン：

Study on prefabrication method for housing in Indonesia by utilization undegradable waste for building material

Siswanti Zuraida[1*], Bart Dewancker[2], Romi Bramantyo Margono[1], Muhammad Arief Irfan[3], Anjar Primasetra[3]

[1] Doctoral Student, Graduate School of Environmental Engineering, The University of Kitakyushu, Japan

[2] Department of Architecture, The University of Kitakyushu, Japan

[3] Department of Architecture, Faculty of Engineering and Design, Institut Teknologi Sains Bandung

*Corresponding author email: siswanti.zuraida@gmail.com

Abstract: *Due to the rapid urban population, Indonesia's housing policy was developed to address the housing backlog that currently, the demand is expected to increase every year. By linkage housing provision and barriers in terms of housing technology, this paper is aimed to propose potential building materials and the construction technology. An experimental study has been conducted to develop disposable diaper waste as potential building materials for composite panel. By constructing the material using prefabrication method with a modular system becomes one of the best choices to accelerate construction speed compared to on site construction. Based on experimental study, maximum replacement of composite material by disposable diaper waste is 30% for wall panel and 5% for floor panel. In addition, the construction cost of prototype housing using prefabrication method is more affordable compared to on site construction.*

Keywords: Housing; Prefabrication method; Disposable diaper; Waste recycling; Building material

1. INTRODUCTION

In the last three decades, the urban population in Indonesia has increased at the average rate of 4.1 per cent per year and it is estimated that 68 per cent of Indonesian will live in urban areas by 2025 [1]. The increasing population in urban areas has the strongest positive in terms of economic growth, as it produces economies of scale for businesses, fosters an innovative environment, and pays higher wages and dividends. [2]. However, the benefits of urbanization are limited [1] due to the challenges that lead to increased poverty, such as the increase in slum-dwelling phenomena caused by a severe shortage of affordable housing [3]. The large increase in urban population also has not considered the availability of land in an urban area and has led to rise of housing demand and land pricing.

Due to the rapid urban population, Indonesia's housing policy was developed to address the housing backlog. Its demand is expected to reach 11.4 million units with 5.4 million units for low-income households [4]. The One Million House (OMH) program is one of the Indonesian government policies to tackle this housing backlog issue that has been progressing since 2015. Within the program, more than 5.3 million units in total have been built until 2021 [5] and will be continued until the backlog is solved. The housing provision, especially for low-income households (LIH) is a new challenge for the Indonesian government to face. Besides political and regulation issues, other potential barriers in terms of technology that must deal with are the high cost of sustainable building materials/technologies and the shortage of skilled labor [6]. Meanwhile, potential success criteria that may become support in low-cost housing provision are construction cost, environmental performance, house price in relation to income and technology transfer [7].

In terms of technology transfer, several alternatives to building materials were calculated and tested as environmentally friendly for substitute materials to overcome the problem of building materials. The use of filler slabs is more economical and environmentally friendly than traditional slabs [8] [9], besides the use of brick panels [8] and bonded brickwork [9] can reduce construction costs compared to traditional bricks. In addition, other technologies for low-cost housing that can be adopted are lime- sand brick, cement -waste slag brick, concrete hollow block, decorative concrete block, and lightweight concrete block [8] and also earthen-based materials [10] [11] [12] [13] such as earth blocks, mud bricks, and earthbag walls. Some researchers even have developed innovations from natural materials such as bamboo wall panels [14] [15], coconut fiber [16] and shredded wood [17]. In addition, the utilization of carbon fiber and jute fiber as reinforced polymers have given benefits in enhancing the shear strength of concrete [18] and various of fibers (natural, metallic, synthetic) also have been investigated in enhancing the tensile strength of concrete [19].

Furthermore, construction technology is essential to increase the speed of construction and reduce costs. For example, by comparing the construction methods for walls using clay bricks and lightweight concrete panels, the cost of conventional construction on clay bricks is higher than prefabrication method on lightweight concrete panel [20]. The prefabrication method is considered to accelerate construction speed [21] and also effective to reduce construction waste [22], and environmental impact [23] [24].

By linkage, the phenomenon of alternative building material and construction, this paper tries to elaborate on the utilization of undegradable waste for building materials by proposing disposable diaper waste as composite materials for building components. An experimental study conducted by several researchers reveal that the application of disposable diaper waste for building materials give a positive result in terms of environmental impact [25] [26], good durability and strength with a maximum mixture of the diaper is 1-5% [27] [28] and no effect in term of healthiness compared to clean diapers [29] [30]. Nevertheless, the previous studies are only limited to the mechanical and physical properties of materials, and the application of materials for building needs to explore more.

Thus, to overcome the limitation, this paper proposes construction techniques for building materials by using a prefabrication system with modular housing elements. Disposable diaper waste in this study is utilized as panel composite materials for wall and flooring and be applicable for low-cost housing concept. The prototype housing design is illustrated with an area of 36 m^2 based on housing minimum standards in Indonesia and applied prefabrication system with hollow steel as structural components and composite panel with dimensions of 60 x 60 cm as architectural components. Then the final is to calculate the construction cost of the housing.

2. METHOD

The method of study is divided into:

1) An experimental study for building materials was investigated by testing the mortar samples consist disposable diaper waste that are used for housing components such as walls and flooring. The application is designed to meet requirements for building materials based on Indonesian Standard (SNI).
2) Housing design and prototyping by applying the materials requirements on experimental study. The housing design also consider minimum housing area based on Indonesian Standard and simulating prefabrication method for housing construction.

3. RESULT AND DISCUSSION

Table 1. Maximum Subsidized Housing Price for Landed Housing in 2016 – 2018 (In million Indonesian Rupiah) [31]

No	Region	2016	2017	2018
1	Java Island (except Jakarta, Bogor, Depok, Tangerang, Bekasi)	116.5	123	130
2	Sumatera Island (Except, Riau Islands and Bangka Belitung)	116.5	123	130
3	Kalimantan	128	135	142
4	Sulawesi	122.5	129	136
5	Maluku and North Maluku	133.5	141	148.5
6	Bali and Nusa Tenggara	133.5	141	148.5
7	Papua and West Papua	183.5	193.5	205
8	Kep Riau and Bangka Belitung	122.5	129	136
9	Jakarta, Bogor, Depok, Tangerang, Bekasi	133.5	141	148.5

3.1 Determine Public Housing Standard in Indonesia

To solve the housing backlog, Indonesian government improve policy to accommodate housing demands. The policy employs two approaches that are: supply-side approach, which was undertaken through larger supply of housing stocks by government and demand-side approach, through housing financing scheme [29]. The government also controls the maximum price for subsidized housing as shown in table 1 and the minimum size requirement is shown in table 2.

Table 2. Standard for Subsidized Housing in Indonesia [32]

Standard per person (m^2)	Housing Area for 3 persons (m^2)	Housing Area for 4 persons (m^2)
Minimum 7.2	21.6	28.8
(Indonesia)	27.0	36.0
9.0		
(International)	36.0	48.0
12.0		

Based on the minimum housing subsidized requirements in table 2, this study illustrate housing prototype design with housing area of 36 m^2 and land area of 60 m^2.

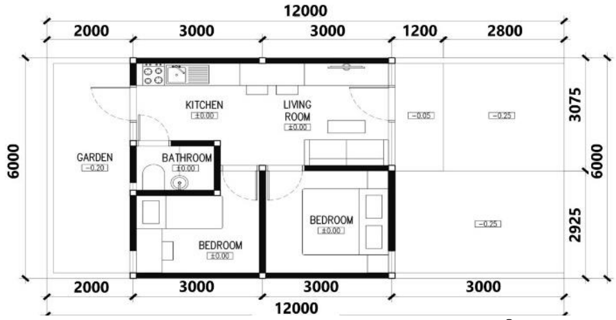
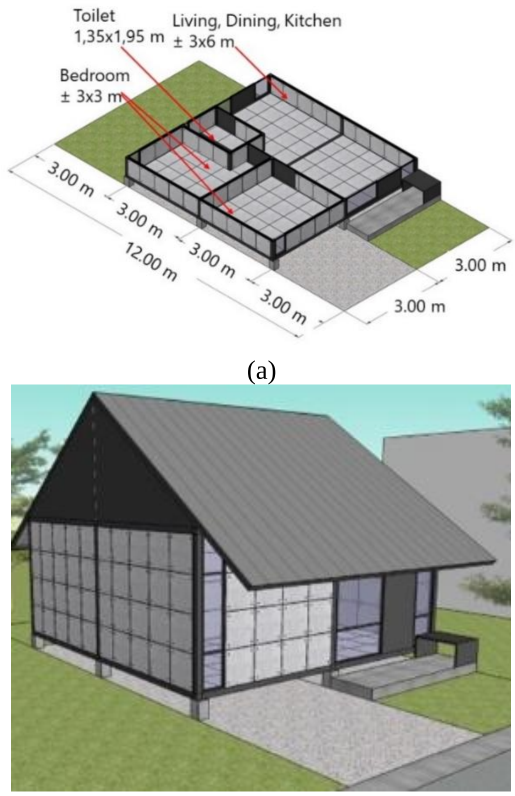


Fig. 1. Floor Plan of Housing Prototype of 36 m^2



(a)

(b)

Fig. 2. (a) Isometric 3D Plan and (b) Perspective View of Prefabricated Housing Prototype Design

3.2 Determine the Formula of Disposable Diaper

Waste Utilization for Building Materials

Two ways approach can be used in utilizing disposable diapers as composite materials for concrete, first as filler or addition and second as replacement of fine aggregates in the concrete compounds. However, to decrease the weight of materials the second way is recommended. Thus, by replacing fine aggregates with disposable diapers, the formula is involved:

$$\text{Rdc} = \%\,\text{rep x} \left(\frac{\rho\ \text{d}}{\rho\ \text{fa}}\right) \text{x mfa} \qquad (1)$$

Where:
Rdc = capacity of recycled disposable diaper (g)
ρd = density of waste disposable diaper (g/cm^3)
ρfa = density of fine aggregate (g/cm^3)
mfa = mass of fine aggregate (g)
% rep = replacement percentage of fine aggregate by disposable diaper (%)

Following the formula, the experimental study had been conducted to measure the compressive strength of mortar which consist of water, fine aggregate, and Portland cement. The mortar standard of building is based on SNI 03-6882-2002 Mortar Specification for Building Materials, which the specification of mortar type is shown in table 3.

Table 3. Mortar Type and Utilization on Building Components

Placement	Building component	Mortar Type Rec.	Fc' MPa	Alt.	Fc' MPa
Outdoor, surface level	Load bearing wall	N	5,2	S / M	12,5 - 17,2
	Wall nonstructural	O	2,4	S / M	12,5 – 17,2
	Supporting wall	N	5,2	S	12,5
Outdoor, under level	Foundation, bearing wall, tunnel, pedestrian ways	S	12,5	M	17,2
Indoor	Load bearing wall	N	5,2	S / M	12,5 - 17,2
	Partition nonstructural	O	2,4	N	5,2
Indoor and outdoor	Shelter and decorative wall	O	2,4	N	5,2

Note:
Rec.: Recommended
Alt: Alternative
Fc': Compressive Strength
Mortar type composition:
M: Portland cement: burnt lime = 2: > ¼ - 1 ¼
N: Portland cement: burnt lime = 1: > ¼ - 1 ¼
S: Portland cement: burnt lime = 1.5: > ¼ - ½
O: Portland cement: burnt lime = 1: > 1 ¼ - 2 ¼

As a result, the experimental study revealed that the maximum replacement of mortar for utilizing as building materials based on SNI is 30% replacement of fine aggregates to disposable diaper and resulting compressive strength of 5.25 MPa. This maximum replacement is utilized for nonstructural component of building, such as partition and decorative wall. For maximum compressive strength, the replacement is limited to 5% and resulting 8.05 MPa and the utilization for building is also limited to structural wall or supporting wall in surface level and indoor. For more information, table 4 shows the results of experimental study.

Fig. 3. Experimental Study of Mortar compounds and Comprehensive Strength Test

Table 4. Experimental Result on Compressive Strength of Mortars and the Utilization

Samples	Strength (MPa)	Utilization
Normal Mortar	11.36	Load bearing wall
MDD 5%	8.05	Structural wall or supporting, surface level, indoor
MDD 10%	6.79	Nonstructural wall or supporting, surface level, indoor
MDD 15%	6.03	Nonstructural wall or supporting, surface level, indoor
MDD 30%	5.25	Nonstructural wall, partition or decorative, indoor and outdoor
MDD 50%	1.11	Not recommended for building components

Note:
MDD : Mortar with disposable diaper waste

Based on the experimental study, the building components for housing is designed with using a maximum replacement of 30% and fits for nonstructural wall or partition for housing. While for flooring, it used 5% replacement with the highest compressive strengths and fits for structural elements.

3.3 Prefabrication System on Housing Components

As a principle, the prefabrication system has been known in developing countries for using local materials based on low technology processes and developed by small industries. It has been developed by simple modules, processes, and efficiency in servicing and delivery that supported the construction company to being more responsive and adaptable to the uncertain market housing on a low scale [33]. In Amerika and Canada, prefabricated housing is known as manufactured house that is supported by steel structure in following mobile home or caravan as dynamic housing that become the ancestor in almost four hundred years. It involves several procedures in manufacturing such as assembly the housing components off site construction location before the component installed in the site construction [34].

Previous study that conducted by the authors [20], had proposed the utilization of plastic waste for wall panel and prefabrication method for construction with varies installation concepts. The studied estimate construction costs for propose prefabricated system by comparing three alternative designs that are construction by hollow steel as a frame, double C channel and on-site construction. The study revealed that hollow steel frame with bolt connection is recommended due to more applicable and low cost compared to other designs.

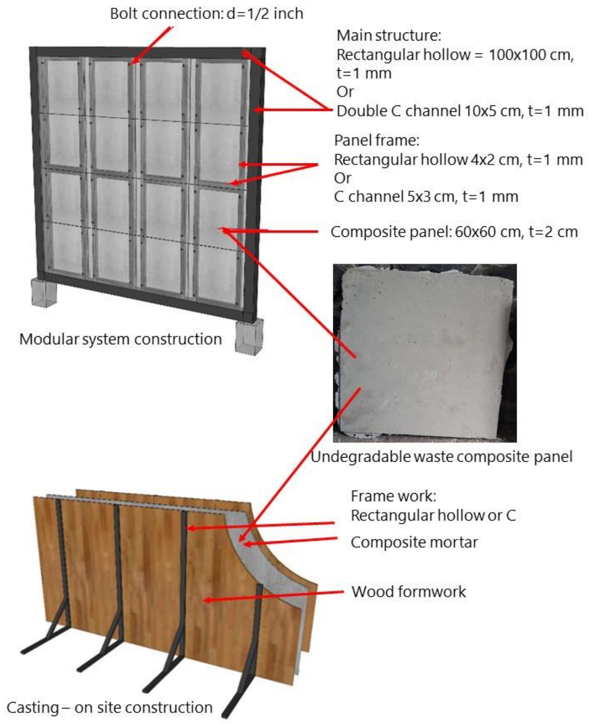


Fig. 4. Comparative study of Installation and Connection Design of Prefabricated Wall Panel

By applying the same concepts, this study tries to elaborate disposable diaper waste for building material in form of panel with dimension of 60 x 60 and proposed to be utilized as wall and floor component of housing. The prototype housing design is illustrated as low-cost housing with housing area 36 m^2 and land area 60 m^2. The structure is developed by using rectangular hollow steel frame with the dimensions of column and beam of 10x10 cm and for panel frame dimension of 2x4 cm. Other buildings components such as roof structure is constructed with rectangular hollow steel frame with dimensions of 4x8 cm and roof sheet is covered with metal roof. While for connection between all elements is using bolt connector.

However, the housing prototype design in this study does not include structural analysis comprehensively. Brief structural analysis conducted to estimate the safety of proposed structure and conclude that the structure has the largest deflection of 7.8 mm and is smaller than the maximum required deflection of 12.9167 mm.

3.4 Construction Cost of Housing Prototype Design

In estimating construction cost of the design, there are some limitations that be considered due to the different technical aspects that involved several phases from clearing the site, construction stages to finishing stage such as coating and installation. In this study, the phases are not identified comprehensive but are limited to the assembly of upper housing components. The understructure of housing such as the foundation is outside of the calculation due to it is needed to elaborate more in terms of soil bearing capacity to determine foundation type and dimension. To interpret the findings and avoid bias, the scenario of construction cost is clearly stated in table 5.

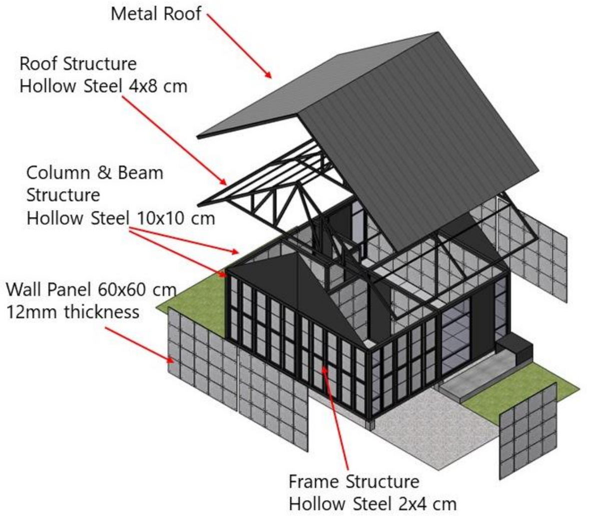


Fig. 5. Exploded Axonometry of Prefabricated Housing Prototype Design

Table 5. Limitation Scenario for Construction cost of prefabricated low-cost housing prototype

No	Construction Phases	Scenario
1	Site work and foundation	Site clearing, trimming, site measurement, soil works, foundation and other works related to site works and under structure are with lumpsum/common cost estimation
2	Rough framing	Column, beam, wall, roof, and other upper structures and building elements are included in the detail calculation
3	Exterior construction	The stage involves installing the windows, doors, siding, plaster work and painting are with lumpsum/common cost estimation
4	Mechanical, Electrical, Plumbing (MEP)	Lumpsum/ common cost estimation
5	Interior construction	Outside the calculation
6	Hardscape and Landscape construction	Paving and planting for outdoor aesthetic are outside the calculation

Table 5 describe construction cost scenario in this study is only limited to site work and foundation, rough framing, exterior construction and MEP installation. Further for unit price analysis is only limited to rough framing due to this scenario is involved whole prefabrication process. While for other works is only estimated by lumpsum scenario. In addition, the price analysis for housing construction is adjusted to

Indonesian standards regarding unit price analysis, i.e.:

1) SNI 2837:2008: The procedure for calculating the price of the plastering unit for the construction of buildings and housing
2) SNI 7394:2008: The procedure for calculating the unit price of concrete works for the construction of buildings and housing
3) SNI 7393-2008 - procedures for calculating the unit price of steel and aluminum work for the construction of buildings and housing
4) Regulation of The Minister of Public Works and Housing, Republic of Indonesia, Number 28/PRT/M/2016: Guidelines for Unit Price Analysis on Public Work

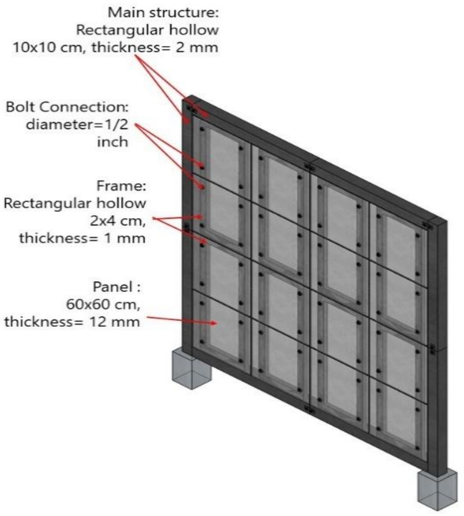


Fig. 6. Isometric of Wall Panel and Frame Construction

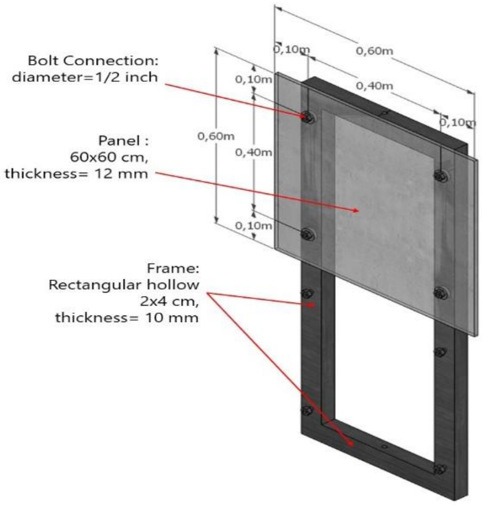


Fig. 7. Isometric Section of Wall Panel and Frame

The region for housing prices is also limited to Java Island, with a case of study in Bandung as an urban city in Java. This case of study is important to be decided because housing construction cost, price of materials and fee of labor is different by region. As a result, construction cost in this study elaborates prefabricated housing components of wall panel and frame construction (figure 6), floor panel and frame construction (figure 8) and other works as shown in figure 5. Thus, the result of the construction cost for each component can be figured out in table 6. Moreover, to capture comprehensive construction cost estimation, table 7 shows the total cost of construction.

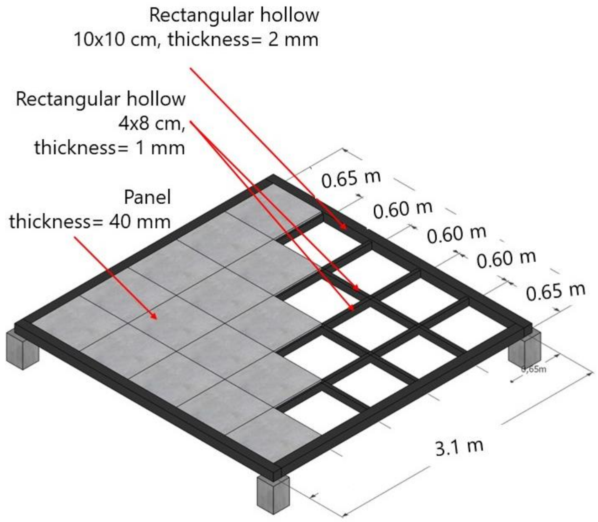


Fig. 8. Isometric of Floor Panel and Frame Construction

Table 6. Construction Cost of Prefabricated Low-Cost Housing Components per m^2

Components	Unit	Unit Price
1. Wall panel - Hollow Steel frame - Bolt connection:		
- Panel, t = 1.2 cm	m^2	148,566.34
- Formwork	m^2	81,286.10
- Hollow steel 2/4 - Bolt connection	m^2	235,033.16
Total Unit Price		464,885.59
2. Floor panel - Hollow Steel frame - Bolt connection:		
- Panel, t = 4 cm	m^2	151,198.84
- Formwork	m^2	81,286.10
- Hollow steel 4/8 - Bolt connection	m^2	284,383.16
Total Unit Price		516,868.09
3. Roof structure - Hollow Steel frame - Bolt connection:		
- Hollow steel 4/8- Bolt connection n	m^2	284,383.16
- Metal cover	m^2	62,768.10
Total Unit Price		347,151.26
4. Column and Beam - Hollow Steel frame - Bolt connection		
- Hollow steel 10/10 - Bolt connection	m	200,628.34
Total Unit Price		200,628.34

Table 7 shows the total construction cost of housing prototype is IDR 120,047,728, which by related to housing price standard in table 1, the housing prototype is affordable.

4. CONCLUSION

This research proposed alternative building materials for housing components by utilizing disposable diaper waste as a composite panel for walls and flooring. The experimental study reveals positive results in terms of compressive strength where the panel composite is meet the required standard of building materials. maximum replacement of composite material by disposable diaper waste is 30% for the wall panel and 5% for the floor panel. Then by proposing the construction system of the panels, the study figures out a housing design prototype to be constructed in the prefabrication method. The structure of construction by utilization of rectangular hollow steel also gives benefits in terms of structural analysis where the deflection does not exceed the maximum and in terms of construction cost, the system is also more affordable compared to on site construction and common housing price in Indonesia. As for the recommendation, the proposed housing prototype design will become more applicable and can be implemented by real constructing the prototype on the site.

Table 7. Construction Cost of Prefabricated Low-Cost Housing Prototype with Area of 36 m^2

Housing components	Vol.	Unit	Unit Price (IDR)	Total Price (IDR)
1. Rough framing:				
- Walls	28.5	m^2	464,886	13,249,239
- Floors	36	m^2	516,868	18,607,251
- Roof structure and cover	62	m^2	347,151	21,523,378
- Columns	36	m	200,628	7,222,620
- Beams	72	m	200,628	14,445,240
2. Site work and foundation	1	ls	20,000,000	20,000,000
3. Exterior construction	1	ls	20,000,000	15,000,000
4. Mechanical, Electrical, Plumbing	1	ls	10,000,000	10,000,000
			Total Construction Cost	120,047,728

5. ACKNOWLEDGEMENTS

The Doctoral Program is financially supported by the Ministry of Education Culture, Sports, Science and Technology (MEXT), Japan. For the research was financially supported by PT. Awina Sinergi International and Matching Fund-Kedaireka Program 2021. The author also acknowledges the research team to Andrie Harmaji, Ilham and Firman Fadhly AR for supporting the laboratory experiment.

6. REFERENCES

[1] W. Bank, "Project Information Document (PID) Concept Stage. National Affordable Housing Program (P154948)," World Bank, 2017.

[2] E. Browne, "Benefits of urbanisation in Asia," GSDRC, University of Birmingham, Birmingham, UK:, 2014.

[3] UN-HABITAT, "Addressing Urban Poverty, Inequality, and Vulnerability in a Warming World," UN-HABITAT and UNDP, 2013.

[4] S. H. Fransiska Ninditya, "Government eyes reducing housing backlog to five million in 2024," ANTARA, 9 2 2021. [Online]. Available: https://en.antaranews.com/news/167660/government-eyes-reducing-housing-backlog-to-five-million-in-2024. [Accessed 3 1 2022].

[5] K. P. U. d. P. Rakyat, "Tingkatkan Kepemilikan Hunian Layak, Realisasi Program Sejuta Rumah Hingga Akhir Oktober 2020 Capai 601.637 Unit," Kementerian Pekerjaan Umum dan Perumahan Rakyat, 2020. [Online]. Available: https://www.pu.go.id/berita/view/18970/tingkatkan-kepemilikan-hunian-layak-realisasi-program-sejuta-rumah-hingga-akhir-oktober-2020-capai-601-637-unit. [Accessed 4 5 2021].

[6] M. A. Adabre, A. P. Chan, A. Darko, R. O. Kyei, R. Adiboye and T. A. Kumi, "Critical barriers to sustainability attainment in affordable housing: International construction professionals' perspective," Journal of Cleaner Production, vol. 253, p. 119995, 2020.

[7] A. P. Chan and M. A. Adabre, "Bridging the gap between sustainable housing and affordable housing: The required critical success criteria (CSC)," Building and Environment, vol. 151, pp. 112-125, 2019.

[8] M. Srivastava and V. Kumar, "The methods of using low cost housing techniques in India," Journal of Building Engineering, vol. 15, pp. 102-108, 2018.

[9] V. W. Y. Tam, "Cost effectiveness of using low cost housing technology in construction," Procedia engineering, vol. 14, pp. 156-160, 2011.

[10] R. Wesonga, H. Kasedde, N. Kibwami and M. Manga, "A Comparative Analysis of Thermal Performance, Annual Energy Use, and Life Cycle Costs of Low-cost Houses Made with Mud Bricks and Earthbag Wall Systems in Sub-Saharan Africa," Energy and Built Environment, vol. x, no. x, p. x, 2021.

[11] M. Gohnert, I. Bulovic and R. Bradley, "A Low-cost Housing Solution: Earth Block Catenary Vaults," Structures, vol. 15, pp. 270-278, 2018.

[12] A. Olotuah, "Recourse to earthfor low-cost housing in Nigeria," Building and Environment, vol. 37, pp. 123-129, 2002.

[13] Y. Kulshreshtha, N. J. Mota, K. S. Jagadish, J. Bredenoord, P. . J. Vardon, M. . C. van Loosdrechtf and H. M. Jonkers, "The potential and current status of earthen material for low-cost housing in rural India," Construction and building materials, vol. 247, p. 118615, 2020.

[14] V. Puria, P. Chakraborttya, S. Ananda and S. Majumdarb, "Bamboo reinforced prefabricated wall panels for low cost housing," Journal of Building Engineering, vol. 9, pp. 52-59, 2017.

[15] D. Larasati, A. Primasetra and Suhendri, "Accelerating Low-Cost Housing Construction in Indonesia: Lesson Learned From Kampong Naga.," DIMENSI − Journal of Architecture and Built Environment,, vol. 44, no. 1, pp. 79-86, 2017.

[16] E. . Q. Bolanos, M. . G. Oviedo, J. M. Bello, L. . S. Vitola, U. Berardi and C. B. Lecompte, "Potential use of coconut fibre modified mortars to enhance thermal comfort in low-income housing," Journal of Environmental Management, vol. 277, p. 111503, 2021.

[17] S. Zuraida and S. Pratiwi, "Analisis Fisik dan Mekanik pada Pengembangan Panel Komposit Limbah Serbuk Kayu," Journal of Applied Science, vol. 2, no. 1, pp. 61-66, 2020.

[18] J. T. Heia, M. M. Islam and A. Islam, "An Investigation towards the Effects of Using Fiber Reinforced Polymers in the Enhancement of Shear Strength of Reinforced Concrete Beams," in International Exchange and Innovation Conference on Engineering & Sciences (IEICES), Fukuoka, 2021.

[19] R. Chakraborty, T. Paul and A. B. S. Ornob, "A Review on Tensile Behavior of Different Kinds of Fiber Reinforced Concrete," in International Exchange and Innovation Conference on Engineering & Sciences (IEICES) , Fukuoka, 2020.

[20] S. Zuraida, A. Primasetra, R. . B. Margono and A. Harmaji, "The Application of Plastic Composite Panel for Prefabricated Low Costs Housing in Indonesia: A Green Construction Design Proposal," Journal of Asian Institute of Low Carbon Design (JAILCD), 2020.

[21] M.-. Hill, "Prefabrication and Modularization, Increasing Productivity in Construction industry," McGraw- Hill Construction, 2011.

[22] W. Lu, W. M. Lee, F. Xue and J. Xu, "Revisiting the effects of prefabrication on construction waste minimization: A quantitative study using bigger data," Resources, Conservation and Recycling, vol. 170, p. 105579, 2021.

[23] O. Pons and G. Wadel, "Environmental impacts of prefabricated school buildings in Catalonia.," Habitat International, vol. 35, pp. 553-563, 2011.

[24] Y. Teng, K. Li, W. Pan and T. Ng, "Reducing building life cycle carbon emissions through prefabrication: Evidence from and gaps in empirical studies," Building and Environment, vol. 132, pp. 125-136, 2018.

[25] S. Zuraida, H. Armijaya, A. Harmaji, R. B. Margono and B. J. Dewancker, "A Calculation Approach of Embodied Energy, Carbon Emission and Eco-Costs on Waste Recycled Composite Materials," Journal of Applied Science and Engineering, vol. 25, pp. 109-118, 2021.

[26] S. Zuraida, B. J. Dewancker and R. B. Margono, "An Environmental Consideration of Disposable Diaper Waste Treatment as Concrete Component," Journal of Asian Institute of Low Carbon Design, pp. 153-158, 2021.

[27] D. Mohamad, S. Beddu, S. N. Sadon, N. . L. M. Kamal, Z. Itam, K. Mohamad and W. M. Sapuan, "Self-curing Concrete using Baby Diapers Polymer.," Indian Journal of Science and Technology, vol. 10, no. 4, 2017.

[28] S. Beddu, D. Mohamad, F. M. Nazri, S. N. Sadon and M. . G. Elshawesh, "Properties of Self-curing High Strength Concrete by using Baby Polymer Diapers," MATEC Web of Conferences, vol. 203, p. 06022, 2018.

[29] H. Karimi, Q. Yu and H. Brouwers, "Valorization of waste baby diapers in concrete," Resources, Conservation and Recycling, vol. 153, p. 104548, 2020.

[30] D. Mohamad, S. Beddu, N. M. Zahari, M. . H. Zawawi, A. Syamsir, N. Radzuan and W. K. M. Sapuan, "The Performance of Diapers Polymer In Concrete As Self-Curing Agent In Term Of Chemical Properties," AIP Conference Proceedings, p. 020186, 2018.

[31] KEMENPUPR, "Batasan Penghasilan Kelompok Sasaran KPR bersubsidi, Batasan Harga jual Rumah sejahtera Tapak dan Satuan Rumah sejahtera Susun, Serta Besaran subsidi bantuan uang muka perumahan," Kementerian pekerjaan umum dan perumahan rakyat, Jakarta, 2016.

[32] KEMENPERPRAWIL, "Pedoman Teknis Pembangunan Rumah Sederhana Sehat (Rs SEHAT)," Kementerian Permukiman dan Prasarana Wilayah, Jakarta, 2002.

[33] C. Davidson, "Myths And Realities Of Prefabrication For Postdisaster," Journal I Rec Building resilience, 2008.

[34] C. Goodier and A. G. F. Gibb, "Future opportunities for offsite in the UK," Construction Management and Economics, vol. 25, no. 6, pp. 585-597, 2007.