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Simple House Construction Innovations Made from PVC Pipes and GRC Boards in Indonesia

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Abstract

This innovation aims to provide a Simple House (SH) Type 24 m² (T-24) floor area made from PVC pipes and Glass-Fiber Reinforced Cement (GRC) boards. The simple house-building structure in this invention consists of PVC pipes and GRC boards which are arranged based on simple building designs in Indonesia. PVC pipes as components of the building space frame and roof are reinforced with reinforced concrete mixed and PVC pipe connections. The potential for users of simple houses for low-income people (MBR) is very large in Indonesia. With a shortage of one million houses per year, the PUPR Ministry is only able to meet 30% or around 400,000 units per year of people's housing needs. The benefit and advantage of innovation is that space frame building construction consisting of floor beams, columns, and ring beams made from PVC pipes is easy to do using relatively simple craftsman equipment. The T-24 simple house innovation is a building that is easy to work on because this building uses materials that can be easily found in various regions in Indonesia, namely PVC pipe materials and GRC boards. In summary, the T-24 simple house prototype has the following innovations: 1) cement brick foundation, 2) construction of floor beams, columns, and ring blocks using PVC pipes and concrete mix without splitting, 3) main roof material structure (rafters and battens) made from PVC pipes, 4) SH T-24 roof covers and walls made from GRC boards, 5) Building features such as doors and windows use a combination GRC boards and glass materials.

Keywords: Innovation, Construction, Simple House, PVC Pipes, GRC Boards

1. Introduction

The global population is increasing by 45 million every year, there is an increase in demand for food, water, and material and importantly housing. The need current level for new housing is forcing the housing industry to encourage construction innovation to use prefabricated materials to accelerate the new housing supply in various parts of the world and various regions of the country (Ramadhiani & Alexander, 2018). The Population growth in Indonesia is increasing day by day. This causes the need for housing to increase over time. The Ministry of Public

Works and Public Housing (PUPR) said that in 2023 it will strive to overcome the housing shortage and encourage the availability of decent housing for the community. Around IDR 11.27 trillion was allocated for residential construction for the community. This is proof of the government's efforts to provide adequate housing for people in need (Kementrian PUPR, 2023). Currently, in the conditions of limitations and poverty that have not yet been resolved 100%, the economic problem is still the only thing that absolutely must be overcome. Meanwhile, the price of building materials is getting more expensive day by day, affecting house prices. This is what causes problems to arise, such as these obstacles to realizing the desire to have a livable house.

One step to answer this challenge is to improve the Indonesian nation's output quality (Okrah, James, Nepp, Alexander, & Agbozo, 2018). Policies to strengthen the community's economy need to be supported by the government, so that they develop over time, cause a country's progress depends on how they increase economic activity (Ram, M., Deakins, 1996). Stable economic conditions help people to realize their dream of having a simple house. Here construction efforts are necessary. Community involvement in encouraging the construction of livable houses through policies that are pro-welfare of the Indonesian people. The need for adequate housing then invites industry construction to innovate to overcome these obstacles. Some of them have innovations or initiatives toward a building house.

Then an idea arose about initiating the construction of a simple house made from PVC pipes and GRC boards, which is an alternative for obtaining a house construction model for low-income communities because of the ease of obtaining materials and the use of relatively easy technology or appropriate technology. This requires cooperation between certain institutions to encourage innovation. The presence of Higher Education (PT) is very much needed to develop innovative works that have use value and benefit the wider community through the educational process (Syahza, 2019). So, the effort to make prototypes through the laboratory's active roles in HEIs involving lecturers, assistants, laboratory assistants, and students becomes very important and very strategic.

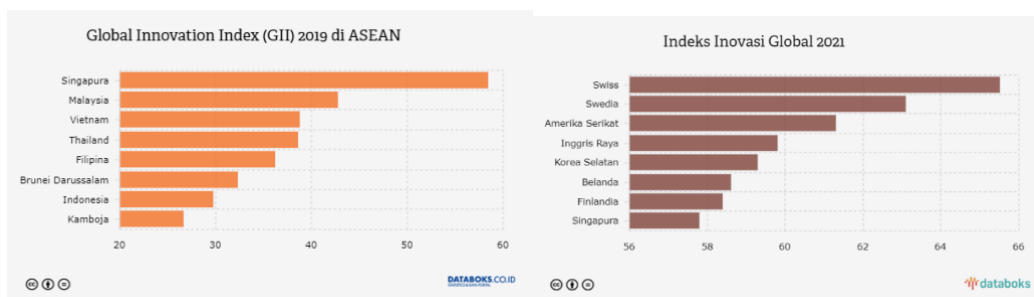


Figure 1: Innovation Global Index and Asean

Source: (Jayani, 2019)

Through this image, we can find out what position Indonesia is currently in. Through this image, Figure 1 shows Indonesia's innovation index position, which is ranked 7th in Asia and not in the top 10 at the global level. This condition is both a challenge and a motivation for PT in Indonesia to continue to increase innovation and transformation so that the benefits value, it can be felt by the wider community over time (Jayani, 2019).

The prototype design for housing construction is the result of scientific developments. This shows the relevance of careful planning to create innovation which must go through the results of trials and research from experts to find out how effectively the design is realized and has implications for achieving satisfaction as expected, namely safe and comfortable development. It cannot be denied that the facts on the ground show that renewable scientific developments are influencing the interest and design of modernist houses, influencing all aspects of life. In its implementation, obstacles often arise such as housing designs that are less affordable for Low Income Communities (MBR). One of the efforts is to create a prototype design as a form of residential construction planning that can be afforded by MBR and is affordable and reliable (Howedi & Jwaid, 2017). The use of fabricated materials can be an alternative for successful construction that is easier to carry out. Moreover, the use of materials that are environmentally friendly or easy to recycle, such as PVC pipe, allows for a fast construction process (Almed et al., 2016).

This research was carried out to present the findings by making the simple prototype that T24, T30, and T36 houses made from PVC pipes and GRC boards, to analyze building construction innovations in the components: 1) Foundation construction; 2) Space frame construction (i.e. tie foundation beams, column, and ring beam construction connections); 3) Construction of truss roofs and roof coverings; 4) Wall construction; and 5) Window door construction. This research was different from previous conventional simple housing studies conducted by (Hadimoeljono, 2016; Kementrian PUPR, 2021; Debnath, 2016) (Hafid, 2011; Cairns, 2021) based on the material and technology used by. Therefore, this current research on building construction and practices can be greatly improved by embracing the industrialization materials of construction. By utilizing local and industrial materials readily available in different regions of Indonesia, such as PVC pipe, GRC sheets, and concrete brick, we will able to revolutionize the innovative construction and potential low-cost housing industry in Indonesia.

2. Literature Review

2.1 State of the Art and Novelty

A popular simple house building is a house building that has sections (Hadimoeljono, 2016), including 1) The foot is a river stone foundation with reinforced concrete tie foundation beams ties; 2) The body consists of walls reinforced by columns and reinforced concrete ring beams and has door and window opening facilities made of wood and glass; with a wooden or light steel frame roof equipped with a clay/ceramic tile roof or concrete tile roof. These simple houses usually have ceramic floors, tiles, or plaster floors. Other construction models such as wooden houses (Kementrian PUPR, 2021; Debnath, 2016) and bamboo houses (Hafid, 2011) (Cairns, 2021) or both combinations. This paper presents a different approach to using materials, technologies, and performances. Materials used in this simple house are 1) cement brick for foundations, 2) PVC pipes and concrete for the building frame, 3) PVC pipes and GRC sheets for the roof construction; and 4) fully GRC boards for the wall construction. This use of materials and technology presents a new innovative potential low-cost housing in Indonesia

2.2 Literature Review

Many Indonesian people want private homes. Even though their income is not much, they are still trying to build their own house. A simple, healthy and pleasant home is the dream of most people. Residences with medium size, affordable prices, and inhabited by people with middle to lower economic conditions. The characteristics of a simple house usually have an ideal plot area or meet the minimum land area requirements. Simple houses strive to support the health of their residents, despite economic limitations, but they have the right to a decent environment, safety and comfort, or simple and healthy. To fulfill the need for decent and affordable housing, there are several considerations that prospective owners must know, such as the surrounding environment, physical building, land conditions, materials, space, and various other related material elements, for the construction of a habitable house. The building in question (simple) is clearly far from having a modern impression or using a luxurious interior. Before building a residence, a person should consider various related things such as the level of security, comfort and support for personal health, strategic location and ease of access (Akmal, 2005). All of this can be realized if house construction is carried out with advance planning, or in the form of a simple house prototype design.

Regarding simple houses, there is a research study from Vincentius Totok Noerwasito which states that each type of building has different energy, and this needs to be taken into account. Especially in the use of materials, if you use materials that have low energy levels, it will affect the energy levels in the building (Noerwasito, 2017). This study emphasizes the need to consider construction materials that are safe and environmentally friendly and have low heat energy.

On the other hand, Dwi Kurniati¹ and Restu Faizah in their study found that house construction that meets technical requirements or complies with development rules is said to be habitable. The construction of houses in the Bantul area of Yogyakarta is carried out by considering the quality of implementation and by the design and having related elements, both structural and non-structural elements (Kurniati & Faizah, 2021). Thus, prototype design or construction design is an urgent matter, especially by related scientific principles. Not far from the study carried out, regarding innovations in simple house construction made from PVC pipes and GRC boards.

Researchers seek to innovate through the results of construction tests carried out with prototype designs as an initial step before construction is carried out.

The approach to solving the problem of the T-30 and T-36 simple house prototypes made from PVC pipes, light steel, and GRC boards with building reliability tests at relatively affordable prices for low-income people can be determined from a review of simple house building elements which include 1) Foundation or feet, 2) Building body or container; and the head or roof of the building (see Figure 2) (Hadimoeljono, 2016).

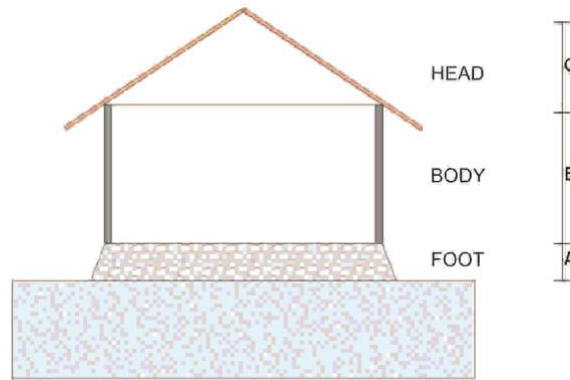


Figure 2: simple building element
Source: (Hadimoeljono, 2016)

Table 1: Elements and Components of a Simple House

RS Element (RS)	RS Building Component
	<p>a. Foot Elements (Foundation):</p> <ol style="list-style-type: none"> 1) Foundation: river stone, padas/white stone 2) Bottom bond tie foundation beams beam; reinforced concrete, wood, etc. 3) Floor: tiles, ceramics, plaster, etc.
	<p>a. Body elements that include</p> <ol style="list-style-type: none"> 1) Column: wood, concrete, glugu, bamboo 2) Upper bond ring beam; wood, concrete, bamboo 3) Wall; brick masonry, woven bamboo, triplex, zinc, etc. 4) Door and window openings: wood, concrete, aluminum, etc.
	<p>c. Head Element (Roof):</p> <ol style="list-style-type: none"> 1) Ceiling or ceiling: cemet fiber, asbestos 2) Roof frame: Wood, light steel 3) Roof covering: concrete tiles, clay, zinc, fiber cement

Source: (Hadimoeljono, 2016)

The structure and construction of conventional Houses or SNI-compliant Houses (Firmanti, 2021) (Debnath, 2016), include several things, including a) River stone foundation elements; b) Elements of the body/living space which are limited by walls that are usually made of plastered brick or light brick with openings such as doors, windows made of wood or aluminum, etc.; c) Roof elements supported by construction trusses made of wood or

light steel or bamboo and others with roof coverings made of tile, zinc, asbestos cement, thatch, and others. (see Figure 3).

2.3 Simple House Construction to Improve Quality of Life

The construction of a simple house is understood as a comfortable place to live, synonymous with a house that is far from modern interior design. The house is made from construction materials at a very affordable cost. Building construction researchers have taken the initiative to build simple houses with attractive designs and low costs. Even though it is low cost, the simple house design still contains a touch of modern design. This construction complies with or meets standard requirements, including stability, strength, resistance to moisture and water, as well as durability, and comfort that is not harmful to humans. In 2017, the World Bank provided approximately \$450 million specifically for the National Affordable Housing Program (NAHP). This project is used to support the construction of affordable housing realization throughout Indonesia. This project is a collaboration with the government and the Ministry of PUPR.

Building a simple house made from PVC pipes is one alternative. This material can be said to be quite light, strong enough, resistant to fire, leaks, and corrosion, and more flexible. These properties are ideal for carrying out its function as a house-building material. House building construction as time goes by, is increasing along with the latest technological developments. In its essence, the house has a significant role in every society, both low-income, middle, and high-class. However, the problem is, that people from middle to lower economic groups, have difficulty building houses because of cost constraints. The increasing rate of structural poverty causes social inequality. In conditions like these, the right alternative is innovation in building livable houses that are affordable for people to live in safely and comfortably and are made from materials that have good durability.

Responding to this, Doxiadis has the view that housing has five elements that constitute an integrated system, including Nature, humans, society, containers, and networks (Doxiadis, 1972). Everything is an interrelated unit and if fulfilled it will run well. A simple livable house can be interpreted in several aspects, namely: philosophical, sociological, health, legal, and physical, as well as energy aspects. At least it fulfills human needs to live comfortably and more humanely. Referring to the Regulation of the State-Minister for Public Housing Number 22 of 2008 concerning Minimum Service Standards in the Housing Sector in Article 2 (1), it states that the Government provides services in the field of public housing so that people can live in livable and affordable houses in a healthy and safe environment. supported by infrastructure and public utilities (PSU).

The concept of sustainable residential development is a development principle that creates building construction that is safe to use and does not have negative implications for the environment, let alone causing detrimental global warming effects. Construction with a green construction theme is an alternative contribution to environmental preservation and improvement. Residential construction efforts made from PVC pipes. The characteristics of this material are non-conductors of electricity or immune to electrochemistry caused by acids, bases, and salts. PVC pipes are made lightweight, are water resistant, have long and short dimensions, have excellent durability, are watertight can handle various leaks, and are sustainable products that do not produce waste and can be recycled. PVC pipes have a long lifespan and do not rot easily, so they are one of the right alternatives as residential construction materials (Pramono et al., 2019).

3. PRO-G House Construction Innovation Methods

3.1 Research Method

This research uses a qualitative approach. The focus is to collect information regarding 'Simple House Construction Innovations Made from PVC Pipes and GRC Boards.' Policy on making simple house prototypes made from PVC and GRC using an architectural approach to strengthen the UII Green Matrix. This research seeks to find effectiveness through efforts to create innovation as an alternative. A simple residential prototype design made with detail. To find the results of the study, researchers used several data collection techniques, namely interviews, observation and documentation. The research informants were subjects who were part of the team in

the simple house construction project. Observations were made by looking at the field and the construction process, documentation by reading several literatures related to this study, and related data.

Different from other research, this study follows previous research conducted by Howedi, & Jwaid regarding the design and implementation of low-cost and multifunctional smart system home prototypes (Howedi & Jwaid, 2017). Then other research by Loss, C., M. Piazza, and R. Zandonini, regarding construction system innovation for sustainable development (Loss et al., 2015). This research identifies the importance of building simple houses designed through the design of habitable house prototypes for middle to lower-economic communities to improve their welfare and have comfortable, low-cost cost, and environmentally friendly housing made from PVC and GRC boards.

3.2 Building and Construction Innovation Methods

This invention aims to provide a house-building structure made from PVC pipes. The house building structure by this invention consists of PVC pipes arranged according to the desired construction design; (The wall and roof elements of the building use GRC (Glass Reinforce Concrete) fabrication materials which are environmentally friendly and easily available on the market or in the community. The process of making a house structure made from PVC pipes consists of the following steps: 1) Installation of brick foundations, 2) Installation construction of tie foundation beams, columns and ring blocks using PVC material and concrete mixture, 3) Installation of the main roof structure (horses and battens) made of PVC material, 4) Installation of roofs and walls made of GRC.

3.2.1 Prototype Design Innovation Method

The prototype design plan that will be carried out is the T-24 Simple House prototype made from PVC pipes and GRC boards (SH T-24 Pro-G) which can be seen in Figure 6. This building prototype uses a brick foundation with space frame walls made from PVC pipes. with reinforced concrete fill without gravel. The walls are constructed using 9 mm GRC board material which is attached to the beam tied to the foundation, columns, and ring beams. The triangular truss frame is made from PVC pipe and battens are made from PVC pipe. The legs of the PVC trusses are filled with reinforced concrete without gravel and the PVC pipe battens are filled with a sand-cement mixture. The roof tiles use 6 mm thick GRC material. "Prototypes provide an overview, to provide specific answers so that product creation can be repeated and improved before it becomes the final product" (Aji, 2018; Planningnotepad.com, 2012).

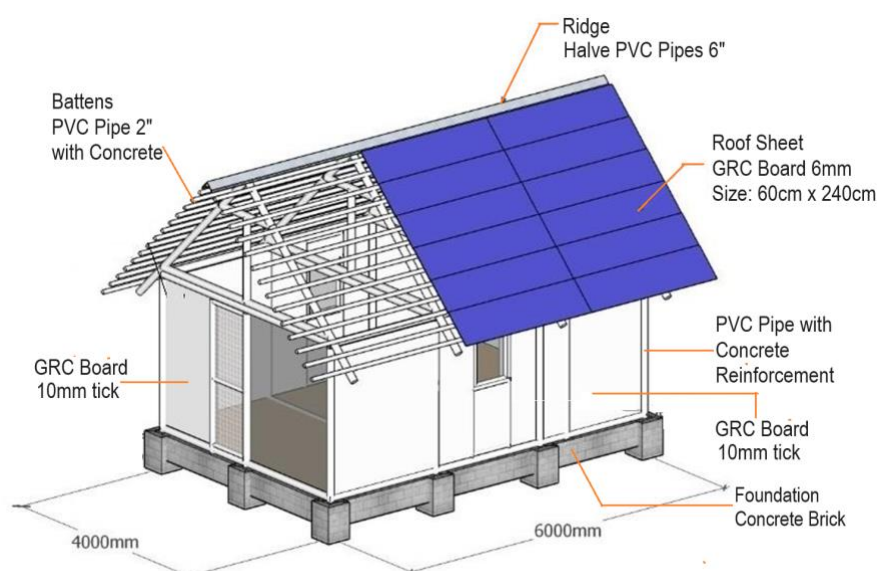


Figure 3: The SH T-24 Pro-G prototype is made from PVC and GRC

The study of making a simple building prototype at the SH T-24 Pro-G will be the basic product for developing a simple house that is environmentally friendly and refers to the SNI for Earthquake Resistant Residential Houses

(Ministry of Public Works, n.d.; Minister of Public Works and Housing, 2016 (Kementerian PUPR, 2017). The SH T-24 Pro-G prototype design will refer to the House, Buildings a Prosperous Home (Ministry of Public Works, n.d.), and the Indonesian National Standard (SNI) for Building Simple Houses - Surabaya Panel Houses. The house area of a simple house according to the State Housing Company (PERUMNAS) is between 12m² to 70 m² with adjustments to the modular system.

3.3 Method for Implementing Pro-G House Innovation Development

The construction stages of the SH T-24 Pro-G are as follows: 1) Preparation, 2) Management, assistance, quality control, monitoring funds, 3) Construction of the SH T-24 Pro-G as a management process for implementing the construction of a simple grow house project. The construction stages of the SH T-24 Pro-G include the following steps: 1) Making the frame, 2) Installing the roof, 3) Installing walls and floors, 4) Installing doors and windows (Suryadi & Cattleya, 2018) which is a technical strategy for the stages of building a simple house. So, these steps will be used for the construction implementation stages of the T-24 Pro-G RS Prototype.



Figure 4: simple house pavilion building

Based on Figure 4 above, researchers are attempting to study prototype products for the pavilion building (see Figure 4). The picture on the bag is an example of the RS T-36 which is made from light steel and GRC board. Then it was developed again with innovations. Starting with the steps to design a simple T-24 house prototype made from PVC pipes and GRC boards. The efforts made by researchers, namely making simple building constructions made from PVC pipes and GRC boards, aim to increase the variety of alternative simple house constructions with a quality that is not much different from residential buildings in general. Several strategies were carried out in the construction of the Pro-G House for construction innovation, including: 1) Preparation of technical drawings for the SH T-24 Pro-G building: Pre-Plan Drawings, Plan Drawings, Detailed Drawings, and Engineering Design (DED), Budget Plans Costs (RAB) and 2) Implementation of Development and Construction of the Pro-G T-24 House.

The next stage carried out was the process of building the RS Pro-G T24 prototype. The initial prototype specifications were developed with the following specifications: 1) Implementation of the Main Structure, including Foundations, tie foundation beams, columns; perimeter beam/ring; and roof structure. The construction process of the main structure must pay attention to dimensional accuracy and use the correct methods; 2) Implementation of roof and wall covering construction, including work: Installation of roof coverings, installation of walls, doors, and windows. Before the implementation stage was carried out, construction design was carried out through a simple house prototype design made from PVC pipes and GRC boards.

4. Data, Analysis, and Discussion

4.1. Location of RS Pro-G Building Site

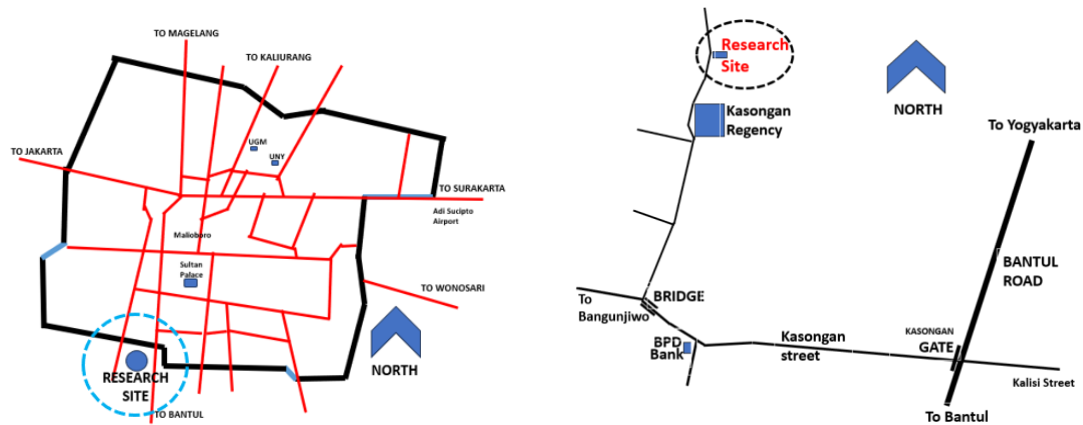


Figure 5: Prototype Location of SH T-24 Pro-G

The picture above is the location for making a prototype of a simple house for testing earthquake-friendly and environmentally-friendly house construction, precisely in the Gang Romowijoyo area, RT:- RW:06 Dukuh Tirto, Bangunjiwo, Kasongan, Kasihan, Bantul, Yogyakarta. More detailed pictures of the construction of the RS Pro-G T24 prototype can be seen in the following stages of development.

4.2. Data on Development and Innovation Implementation of Pro-G T24 House

4.2.1. Construction Implementation

4.2.1.1. Foundation Work

4.2.1.1.1. Making Uitzet Bouwplank



Figure 6: Uitzet Bouwplank Construction

The construction of the bow plank utility refers to the SH T24 Pro-G prototype with a floor area of 24 m², namely a building width is 4m and a building length is 6m. The location of the building is 3 meters from the east fence and 1 m from the north fence of the land or land boundary.

4.2.1.1.2. Excavation of land



Figure 7: Excavation of Land

4.2.1.1.3. Foundation Construction



Figure 8: Foundation Construction

The foundation material is a mixture of cement sand and brick. The choice of material is adjusted to the load on the roof, walls and main structure.



Figure 9: Foundation Installation

Installation of the foundation in the form of a pair of 10x20x40 bricks glued with a cement-sand mixture with a ratio of 1:4.

4.2.1.2. Tie foundation beams, Column and Ring Beam Work

4.2.1.2.1. Tie foundation beams Works



Figure 10: Tie foundation beams Process

1. The tie foundation beam material is 1) PVC pipe (PVC) with a diameter of 4 inches, 2) a cement-sand mixture with a ratio of 1:3 and 3) iron reinforcement with a diameter of 10 mm.
2. Installation of the tie foundation beams is done by cutting and installing PVC pipes connected to the fitting. Next, the PVC pipe is filled with 10mm iron reinforcement and after the steel reinforcement enters the PVC pipe, it is tied to each other in the pipe. After bonding the reinforcement in the PVC pipe, cement sand casting is carried out.

4.2.1.2.2. Column Works

1. Column materials are 1) PVC pipe (PVC) with a diameter of 4 inches, 2) a mixture of sand cement ratio 1:3, fitting 4 inches, and 3) iron reinforcement with a diameter of 10 mm.
2. Column installation is done by cutting and installing PVC pipes connected to the fitting. Next, the PVC pipe is filled with 10mm iron reinforcement and after the steel reinforcement enters the PVC pipe, the reinforcement is tied to each other in the pipe. After bonding the reinforcement in the PVC pipe, cement sand casting is carried out.



Figure 11: Column Works

4.2.1.2.3. Ring Beam Job



Figure 12: Ring Beam Job Results

- i. The ring beam material is 1) PVC pipe (PVC) with a diameter of 4 inches, 2) a mixture of sand cement ratio 1:3, fitting 4 inches, and 3) iron reinforcement with a diameter of 10 mm.
- ii. Installation of ring beams is done by cutting and installing PVC pipes connected to fitting. Next, the PVC pipe is filled with 10mm iron reinforcement and after the steel reinforcement enters the PVC pipe, the reinforcement is tied to each other in the pipe. After bonding the reinforcement in the PVC pipe, cement sand casting is carried out.

4.2.1.3. Roof Truss Job

4.2.1.3.1 Truss Frame Job



Figure 13: horse frames process



Figure 14: truss frames installations

4.2.1.3.2. Batten Work Process

1. Manufacture of battens



The batten material uses 1.25-inch PVC pipes and is filled with a sand cement mixture with a 1:3 ratio

2. Batten Installation



The battens are installed on the pralon trusses leg by bolts means. The distance between the battens is 50 cm taking into account that the roof covering (tile) uses GRC board material with 6 mm thickness.

4.2.1.4. Tile Job

4.2.1.4.1. Roof tile material



The tile material used is a 6 mm thick GRC board with a size of 60 x 240 m² and using the original GRC board module measuring 120 x 240 cm² by dividing it by 2 with 60 cm width. Next, the GRC board tiles are painted (tile paint) blue.

4.2.1.4.2. Roof tile Installation



Roof tile material (60x240) is installed on PVC pipe battens (containing hardened sand cement) at a distance of 50 cm by bolting. Its overlap between roof tiles is 10cm to prevent water from entering. Meanwhile, for tile boards longitudinal joint, aluminum profile H 6 mm, 5 cm wide, and 55cm long is used.

4.2.1.5. Wall Works

4.2.1.5.1. Materials



The wall material is used on the GRC board which functions for the wall area and wall frame.

4.2.1.5.2. Installation



The wall installation uses GRC boards combined with GRC board frames to produce walls that also function as shelves or even cupboards. GRC frames can be used with GRC thicknesses of 8mm, 9mm, or 10mm. Meanwhile, GRC frame width can be used at 10 cm or 15 cm according to the thickness of the wall/shelf being designed.

4.2.1.6. The door and window job

4.2.1.6.1. Material



The door and window materials use the GRC board which functions for the door leaf and door or window frames/frames. The thickness of GRC boards for doors and windows varies between 8mm, 9mm, or 10mm according to the needs and construction or design appearances.

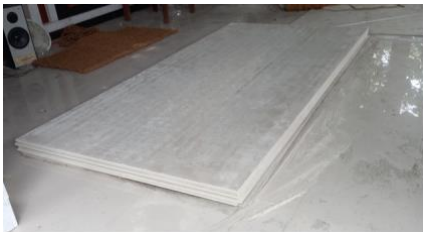
4.2.1.6.2. Installation



From the photo next to it, it can be seen that the GRC board material is very flexible in its use for doors and windows. In the RS T24 Pro-G building, door frames were installed in a minimalist style, and wide glass windows were installed with frames that had a 60cm² frame module. The door leaf will be made using GRC boards, while the wide windows with GRC frames will be installed with the GRC 6mm thick.

4.2.1.7. Kitchen Job Process

4.2.1.7.1. Material



The kitchen spelling material uses GRC board which functions for the table area and table frame. The thickness of GRC boards for doors and windows varies between 8mm, 9mm, or 10mm according to the needs and appearance of the construction or design.

4.2.1.7.2. Installation



The GRC board is made in doubles to function as a vertical table frame and a kitchen table surface which is installed in doubles horizontally.



The use of GRC boards for walls is very flexible. The side image shows the outer kitchen wall button that uses GRC boards for plant shelves, which means it is a green wall based on GRC shelves and plants.

4.2.1.8. The floor Job Process

4.2.1.8.1. Material



Materials for the floor are cement sand mixture for the plaster floor and 6mm GRC board for the floor covering. As a finish, the GRC floor covering boards are painted with waterproof paint. GRC boards for floor coverings are given a 60x60 pattern before painting the floor.

4.2.1.8.2. Installation



The GRC board installation for floor covering. The GRC board has been given a 60x60 floor pattern. The next floor job is finishing the floor paint.

4.3. Analysis and Discussion of RS Pro-G T24 Innovation

Residential construction with a 'simple' or low-cost theme is starting to become a concern for some people. They realize that this construction innovation has a positive impact on economic growth, such as stimulating demand for energy-saving services and business opportunities or start-up, then implication is to create new Works in the construction sector (Nallathiga et al., 2022). Environmentally friendly home has received attention from foreign countries, one of which is the United States. House building construction is directed at cost savings thereby contributing to economic growth. With this alternative, various groups of society, including the lower middle class, can access construction financing. Meanwhile, based on study result by the University of California, Berkeley found that certified buildings actually have very high sales compared to non-environmentally friendly certified buildings (Eichholtz et al., 2010). Construction at affordable costs plus environmentally friendly material use is very profitable. The simple house construction with environmentally friendly concept using PVC pipes and GRC boards as basic materials has gone through trial results. A prototype design is made first to see whether the results of this innovation are suitable or not. The construction implementation went through several job stages using appropriate technology.

In this research, there are several construction findings or innovations by looking at the details of the development process. There are structural innovation number found from this construction, including several things: a) Roof. With a gable roof shape, the pralon PVC pipe material and GRC boards are easy to support this shape. Even the roof covering is very easy to form with GRC boards in wider and lighter sheets. So installation is easier and faster than traditional roof tiles or concrete roof tiles. A material that is similar in area to GRC board is zinc type material. b) On walls, doors and windows. 1. Wall. From the construction aspect, the RS T24 wall is very special, because the wall uses GRC board material and a GRC board frame where the results of this construction not only produce walls but also produce shelves or cupboards. Even on the facade (outer face) the wall produces shelves that can be

used to place plants so that the wall supports green building construction. 2. Door. Doors are generally made of wood iron or zinc, and other materials. However, on the RS T24 Pro-G, the door is made from GRC board which is the construction of the door leaf and door frame. 3. Window. In general, windows wood made or aluminum. However, in the RS T24 Pro-G, the windows are made from GRC boards which are the door leaf and door frame construction. c) Construction findings on floors and foundations. As for the floor itself, the floor is generally plaster-made and covered with tiles, ceramics, granite, carpet, etc. However, in the RS T24 Pro-G, the floor is plaster and covered and made with GRC board with a checkered tile pattern measuring 60x60 m². Next, the GRC plank floor is finished using water-resistant and colored paint. Even the RS T24 Pro-G floor paint can have various colors in gradations, for example, rainbow colors. Meanwhile for the foundation, because the RS T24 Pro-G material is relatively light, the foundation is constructed with the material.




All of the materials used in RS T24 Pro-G construction (namely PVC pipes and GRC boards) are materials that are easy to obtain in urban and rural communities at affordable prices. Both materials are easy to destroy or reuse, thus supporting sustainable construction aspects. After simple house construction has been carried out, another alternative can also be implemented, namely T-36 house construction through the following stages, namely: 1) The preparation process includes several activities, such as land clearing; land measurement; and bow plank installation. 2) Foundation work, including; Earth excavation work for foundations, embankment work, based material, installation of stone foundations (river or mountain type), and earth embankment work. 3) Reinforced concrete work for casting tie foundation beams, ring beams, terrace columns, and practical columns. Process scope: concrete molding, reinforcement, using cement labeled SNI, fine aggregate using appropriate technological machines. 4) Installation work, including Wall installation, plastering, and floor finishing. 5) Window and door work. 6) Ceiling and roof work. 7) Work on plumbing installations, including Installation of clean water installations, installation of dirty water pipes, and sanitation. 8) Lastly, paint, either wood or wall paint. 9) Electrical processing process so that electronic use is safe. 10) Locking and hanging work. The construction here for windows can also install the glass neatly so that there are no gaps that allow strangers to enter the room.

The overall trial construction of a simple house is appropriate and has a time span that is not that long. The design is made to see the effectiveness and quality of the building. Furthermore, what is unique or special about this invention is that this simple house has a construction made from PVC pipes as the main structure of the building (tie foundation beams, columns, tie beams which are assembled with PVC steel) and wall and roof building components made from GRC which are connected to the components. PVC with bolts. The house building structure according to this invention has technical and non-technical advantages, including being able to provide strength, lightweight, rust resistance, and non-flammability; dampens electric currents (as good insulation), is resistant to chemicals and is easy to shape and adapt to all forms of house building designs and is relatively affordable. The following is an innovation in the structure and construction of a simple house made from PVC pipes, light steel, and GRC boards (RS Pro-G).

Based on the trial result simple house implementation construction made from PVC, the prototype components functionality was ensured to be implemented well and according to the design made. When everything has been applied correctly. The entire system operates by the design and the results are very supportive, starting from making foundations, working on tying foundation beams, doors, windows, walls, floors, or other things that are assembled according to the initial design of the prototype. The predetermined sizes of PVC pipes and GRC boards are very helpful in the construction process. The result is quite a solution. Because these materials price is very affordable. The building construction uses environmentally friendly basic materials and is resistant to any weather, including the rainy season and summer (Almed et al., 2016).

The urgent reason why you use PVC pipes is because the durability of PVC pipes is around 30 years. One of the advantages is that its potential can reach permanent limit house needs in general. Likewise, GRC boards are a material that is strong enough for semi-permanent buildings and flexible to use for building construction. These two basic materials' qualities are beyond doubt. People are only given the option to choose any thickness according to their needs. Residential construction made from GRC and PVC has positive and supportive implications for the concept of a simple house. Such as: 1) Environmentally friendly, because GRC board shelves can be made into wall shelves on which ornamental plants pots then be placed in a position to adjust sun direction. 2) Both GRC and PVC pipe materials are recyclable materials that can be recycled so they do not create new waste.

Table 3: Innovation Findings for Simple House Elements and Components

Simple house element	Innovation building component
	<p>a. Foot Elements (Foundation):</p> <ol style="list-style-type: none"> 1) Foundation: brick; 2) Bottom bond tie foundation beams beam; PVC pipes are cast with sand cement and reinforced with iron reinforcement; 3) Floor: Plastered and 6mm GRC boards painted in color with road marking paint.
	<p>b. Body elements that include</p> <ol style="list-style-type: none"> 1) Columns and ring beams: PVC pipes are cast with sand cement and reinforced with iron reinforcement; 2) Wall; Papa GRC; 3) Door and window openings: GRC Board and Ribbon Glass & Ice Glass.
	<p>c. Head Element (Roof):</p> <ol style="list-style-type: none"> 1) Ceiling or ceiling: Fabric, GRC; 2) Roof frame: PVC pipe (cast with sand cement and iron reinforcement) or light steel; 3) Roof covering: 6mm GRC board & Tile paint.

Source: (Suparwoko, Teguh, M., & Aldiansyah, 2022)

This development has various innovations. First, innovation in the use of materials, technology, and architecture in simple residential construction, including: Using bricks for foundations, PVC pipes and concrete without gravel, and walls with GRC boards. Meanwhile, the appropriate technological innovation used in the construction process includes two things: a) Technology for installing brick foundations using a hoe and spat for mortar and fitting. b) Wall and roof installation technology that uses a grinder/saw and electric drill as well as fastening bolts.

Second, product innovation is easy, fast, and affordable. Includes: 1) Building component innovations such as brick foundations, reinforced concrete PVC pipe frames, GRC board walls, GRC plank floors with road marking paint or floor paint, and finally GRC roofs with concrete PVC roof frames. 2) Cheap and fast construction seen from the manufacture of doors without frames and glass windows with very thin GRC frames, and 60x240 GRC sheets for roofs with bolted construction.

The Simple House (SH) construction results made from PVC or PVC pipes (SH Pro-G) and GRC boards have the potential for structural durability that needs to be tested further. The semi-permanent house advantage can produce development innovations that are livable and have an environmentally friendly character because the basic materials are easily recyclable and earthquake-resistant. The technology uses fast and effectively produce aesthetically pleasing RS products that are an alternative worthy of simple home construction for people in all circles.

5. Conclusion

The newest construction alternative is simple house construction made from PVC pipes and GRC boards. The development of innovation through prototype design is intended to ensure that planning is right on target and implementation of development is by the results of studies by researchers. The innovations discovered by researchers (including foundations, space frames using PVC pipes, and roof material and construction), have contributed as an alternative to building simple houses for various groups of people, especially low-income people with relatively affordable material prices.

PVC pipe and GRC board materials have some advantages: 1) the material is easy to obtain in various urban and rural areas throughout Indonesia, 2) the price of the material is relatively affordable; 3) materials are environmentally friendly because they can be recycled, 4) the manufacture of RS Pro-G is carried out using the right technology so that it is easy for most craftsmen or workers in Indonesia.

RS T24 Pro-G is a simple building that is easy to build easily and with affordable material prices and uses appropriate technology, which means the equipment used is quite simple and plentiful and is commonly used by craftsmen in Indonesia. The use of RS T24 Pro-G needs to be socialized to the wider community. It is necessary to complete research on the structure of the SH T24 Pro-G to support complete safety and building reliability.

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