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Construction Planning, Cost Analysis, and Sustainable Design Strategies for the Rehabilitation of Official Residences in Surabaya, East Java

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Abstract

Official residences in Surabaya, East Java, are facing severe physical degradation characterized by structural damage, reduced comfort, and noncompliance with modern housing standards. Rehabilitation efforts have traditionally prioritized short-term construction costs while overlooking sustainability, energy efficiency, and long-term livability. This study develops an integrative framework for rehabilitation by combining construction planning, cost analysis, and sustainable design strategies. Field surveys documented existing conditions, while technical inspections assessed material and structural performance. Rehabilitation plans were prepared through technical drawings, work schedules, and material requirements, with cost analysis based on national standards comparing conventional and environmentally friendly materials. Sustainable strategies included natural lighting, cross-ventilation, energy-efficient systems, and the use of local eco-friendly materials. Findings reveal that sustainable design not only enhances energy efficiency and occupant comfort but also extends building life cycles and reduces long-term operational costs. The proposed model demonstrates that a balanced integration of technical, financial, and environmental considerations produces more resilient and livable government housing. The novelty lies in its holistic approach, rarely applied to official residence rehabilitation in Indonesia, offering practical insights for policy and advancing civil and environmental engineering practices toward sustainable housing management.

***Keywords**: Construction Planning, Cost Analysis, Environmental Sustainability, Rehabilitation, Resilient Housing*

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INTRODUCTION

The development of Surabaya as one of Indonesia's major centers of government, economy, and education has significant implications for infrastructure needs, including the provision and maintenance of official residences for government officials and civil servants (Siswoko & Widyawati, 2021; Yudha & Widiyarta, 2024). Official residences, which are expected to function both as adequate living spaces and as supportive facilities for work, are increasingly facing serious physical degradation (Arumsari & Rarasati, 2017). A considerable number of such residences in Surabaya have experienced structural damage, declining comfort quality, and conditions that no longer meet modern housing standards (Alfauzi et al., 2025; Pamungkas et al., 2021). This situation is not merely a technical issue of building deterioration, but also concerns state budget efficiency, urban environmental sustainability, and the well-being of residents who depend on the livability of these houses.

This problem is further compounded by the fact that rehabilitation planning for official residences generally prioritizes short-term construction costs. Environmental sustainability, energy efficiency, and long-term comfort are often overlooked. If rehabilitation strategies are limited to replacing damaged materials and repairing structural components without considering energy performance, ventilation, or sustainable design, maintenance costs in the coming years will inevitably escalate (Pamungkas et al., 2024; Tjandra et al., 2021). This underscores the urgent need for a more comprehensive rehabilitation model, one that not only considers upfront expenditures but also integrates long-term benefits and sustainability.

This condition is consistent with various reports on the quality of government infrastructure. Data from the Audit Board of Indonesia (BPK) and the Ministry of Public Works and Public Housing (PUPR) over the past few years indicate that many government buildings have suffered functional decline due to the absence of long-term maintenance planning. Moreover, global trends in urban development demand that large cities, including Surabaya, increasingly integrate sustainability principles into infrastructure policy (Dewa & Buchori, 2021; Surya et al., 2021). Therefore, the rehabilitation of official residences must no longer be perceived as mere physical repair but rather as part of a sustainable, efficient, and environmentally responsible urban strategy.

Several prior studies have highlighted the importance of integrating construction planning with cost considerations and sustainability. For example, Arifin et al. (2023) and Silver (2024) emphasized that well-planned construction reduces resource waste and extends building lifespan. Meanwhile, Kelly-Fair et al. (2022) and Liun et al. (2022) found that combining cost analysis with environmentally friendly material selection could reduce long-term operational costs by up to 25%. Similarly, Shofy & Wibowo (2023) argued that applying sustainable design principles in government housing not only improves residents' quality of life but also reduces urban carbon emissions.

In the Indonesian context, several studies have touched on similar issues. Hamit et al. (2023) and Waseso et al. (2024) noted that public building rehabilitation often faces budget constraints, leading to short-term cost-saving approaches that compromise quality. Bonita & Wadley (2022) and Sayer et al. (2021) showed that the use of sustainable local materials not only reduces costs but also enhances community involvement in the construction process. Likewise, Fuady et al. (2025) and S.-S. Liu et al. (2023) highlighted that most government official residences in major Indonesian cities fail to comply with international energy efficiency standards.

Other research has further enriched the discussion of sustainable design in construction projects. Haqq & Gultom (2021) and Sagala et al. (2025) stressed that sustainable building design is not merely a technical matter, but also a form of social responsibility toward the environment. The green building concept, as discussed by Agyekum et al. (2021), T. Liu et al. (2022), and Meng et al. (2021), provides a strong rationale that higher initial investment can yield significant savings in energy and operational costs over time. Meena et al. (2022)

and Yang et al. (2022) further suggested that economic evaluations of construction projects should adopt a life-cycle perspective rather than focus solely on initial construction costs.

The literature also indicates that the rehabilitation of government residences has rarely been studied from an integrative perspective. Azizah et al. (2023b) and Setyonugroho & Maki (2024) concentrated primarily on project management aspects, while Tjitrawati et al. (2024) and Wahyuni (2023) focused only on cost efficiency without incorporating sustainable design. Although T. Liu et al. (2022) developed an integrative model for public housing in China, differences in social and regulatory contexts prevent direct application in Indonesia. Furthermore, Azizah et al. (2023a) and Nurrahman et al. (2023) underscored the contextual barriers to implementing green building practices in developing countries, emphasizing the need for more locally adapted approaches.

A review of these studies reveals a clear research gap in the scientific discourse on the rehabilitation of official residences in Indonesia, particularly in major urban contexts such as Surabaya. Existing studies tend to examine the issue from isolated perspectives, whether construction planning, cost analysis, or sustainable design. Yet these dimensions are inherently interconnected and inseparable if the ultimate objective is to produce government housing that is livable, cost-efficient, and sustainable. This gap presents an opportunity to develop a rehabilitation model that integrates construction planning, cost analysis, and sustainable design strategies within a single comprehensive analytical framework.

The novelty of this study lies in its effort to integrate these three dimensions into a unified and applicable evaluation framework. This approach ensures that rehabilitation results in residences that are not only physically restored but also more energy-efficient, comfortable, and environmentally friendly. The long-term perspective adopted here distinguishes this research from previous studies, as the focus extends beyond short-term cost savings to encompass the overall benefits throughout the building's life cycle.

Accordingly, this study aims to (1) develop construction planning for the rehabilitation of official residences in Surabaya that is efficient and compliant with technical standards, (2) conduct cost analysis comparing conventional schemes with sustainable alternatives, and (3) evaluate design strategies that improve comfort, energy efficiency, and environmental sustainability. The findings are expected to generate a rehabilitation model that balances cost, technical feasibility, and environmental sustainability, thereby contributing significantly to the fields of civil and environmental engineering, particularly in the context of government infrastructure management in Indonesia.

RESEARCH METHOD

The research methodology was designed to address the complexity of challenges in rehabilitating official residences in Surabaya while producing findings that are both practically applicable and academically valuable. The choice of Surabaya as the research site is deliberate. As one of Indonesia's largest administrative centers, the city has a significant number of official residences, diverse in both function and physical condition. Many of these residences are more than three decades old, with evident structural and non-structural deterioration. This makes Surabaya a natural laboratory for examining how construction planning, cost analysis, and sustainable design strategies can be applied in real-world contexts rather than as mere conceptual simulations.

The first stage of the study involved field surveys conducted directly at the selected official residences. The purpose was to obtain a comprehensive picture of the existing building conditions, ranging from structural damage such as wall and foundation cracks to non-structural issues like roof leaks, fading paint, and inadequate ventilation systems. Documentation was carried out through photographs and descriptive records, thereby providing a solid foundation for subsequent analysis. This approach was deemed relevant because actual building conditions cannot be fully represented through administrative documents or written reports alone.

The second stage comprised technical testing, which included examining material quality and structural strength. These tests were essential for determining whether existing materials could still be retained or required replacement. For instance, concrete testing was conducted to assess compressive strength in line with Indonesian National Standards (SNI), while timber and steel tests were performed to evaluate degradation caused by aging and environmental factors. Technical testing was crucial because effective rehabilitation must be based on objective knowledge of material conditions, rather than visual assumptions, thereby minimizing the risk of cost overruns due to misestimation.

Once the field conditions and material quality were mapped, the next step was the preparation of construction planning. This stage produced technical documents comprising working drawings, implementation schedules, and material requirement analyses. Planning extended beyond technical aspects to also consider efficiency in labor and time. As noted by L. Liu et al. (2024) and Omrany et al. (2023), comprehensive construction planning is fundamental to project success because it anticipates potential constraints while maximizing resource utilization. Thus, the planning documents generated in this study were designed to serve a dual function: as practical references for rehabilitation implementation and as academic tools for evaluating construction planning approaches in government settings.

Subsequently, cost analysis was undertaken to assess the financial feasibility of rehabilitation alternatives. Calculations were based on applicable SNI standards and compared conventional material use with environmentally friendly options. The analysis not only accounted for initial construction costs but also incorporated long-term operational expenses. As argued by Omrany et al. (2023), economic evaluations in construction should adopt life-cycle analysis, since post-construction costs often outweigh initial investment. This method was therefore selected to provide a comprehensive picture of the financial implications of each proposed rehabilitation option.

The next phase involved sustainable design evaluation, focusing on the integration of energy efficiency, natural lighting, cross-ventilation, and the use of local eco-friendly materials. Both quantitative and qualitative approaches were employed. Quantitatively, simulations were used to measure potential energy savings through lighting and ventilation improvements. Qualitatively, short interviews with residents were conducted to capture perceptions of spatial comfort, as human-centered factors are key indicators of sustainable design success (Tuanaya, 2024). This mixed approach ensured a more holistic understanding by linking technical parameters with lived experiences of residents.

Data validation was achieved through triangulation, combining results from field surveys, technical testing, and expert input in construction planning and sustainable design. Triangulation was chosen to enhance data reliability by cross-verifying information from multiple sources, thereby minimizing bias that might arise from a single method. Additionally, cost analysis results were validated against the latest SNI standards and compared with current material prices in Surabaya. This ensured that the research findings were robust and defensible from both academic and practical perspectives.

RESULTS AND DISCUSSION

Preparation of Construction Rehabilitation Plans

The preparation of construction rehabilitation plans for official residences in Surabaya was carried out through a systematic sequence of stages, starting with an analysis of existing conditions, the drafting of technical drawings, the calculation of material requirements, and the preparation of work schedules in accordance with construction management principles. The primary objective of this stage was to ensure that all rehabilitation work could be executed not only in a technically sound manner, but also with due consideration for cost efficiency, time accuracy, and the integration of sustainability principles. According to Buda et al. (2021), the integration of construction planning with energy efficiency strategies in public projects enhances building durability while simultaneously reducing resource waste. Therefore, the rehabilitation plan was developed comprehensively, covering structural, architectural, and mechanical, electrical, and plumbing (MEP) aspects.

The design development stage was undertaken to provide each scope of work with a clear direction tailored to field requirements. The analysis was divided into several categories of work, namely structural works, architectural works, and MEP works. Structural works represented the most critical component as they pertain to building strength and safety. Architectural works focused on spatial quality and aesthetics in line with modern housing standards. Meanwhile, MEP works ensured that the residences would adequately support occupant comfort and functionality.

For structural works, the foundation was the first element analyzed. The rehabilitation employed two types of foundations, namely stone masonry foundations and pilecap foundations. Stone masonry was selected for its capacity to bear loads at relatively lower cost, whereas pilecap foundations were used to reinforce columns in areas with heavier loads. Both were designed to suit the soil conditions in Surabaya, which largely consist of medium-bearing clay.

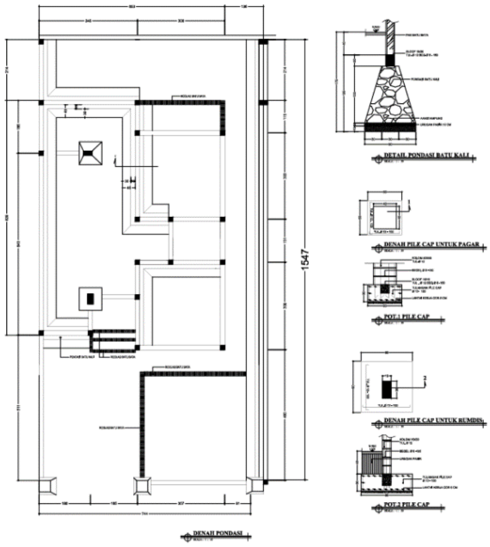

Figure 1 Foundation Structure Plan of Official Residence, Jl. Manukan Tengah
Source: Detailed Engineering Design (DED) Consultant, 2020

The next stage concerned sloof, columns, and beams. In this project, sloof was designed with dimensions of 15/20 and 15/15, while columns were designed with dimensions of 15/15 and 15/30. Beams were designed at 15/15 dimensions to accommodate floor and roof loads. These size specifications were critical to ensure that the building would not only be structurally sound but also economical in material use. The design referred to SNI 2847:2019 on structural concrete as the principal guideline for dimensioning and concrete material quality, thereby ensuring compliance with national safety standards.

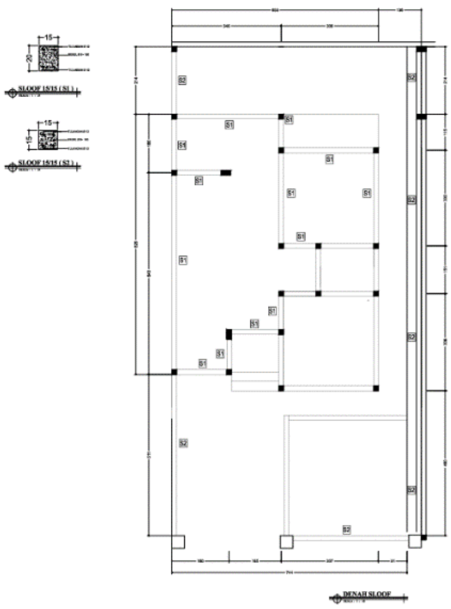

Figure 2 Sloof Structure Plan of Official Residence, Jl. Manukan Tengah
Source: Detailed Engineering Design (DED) Consultant, 2020

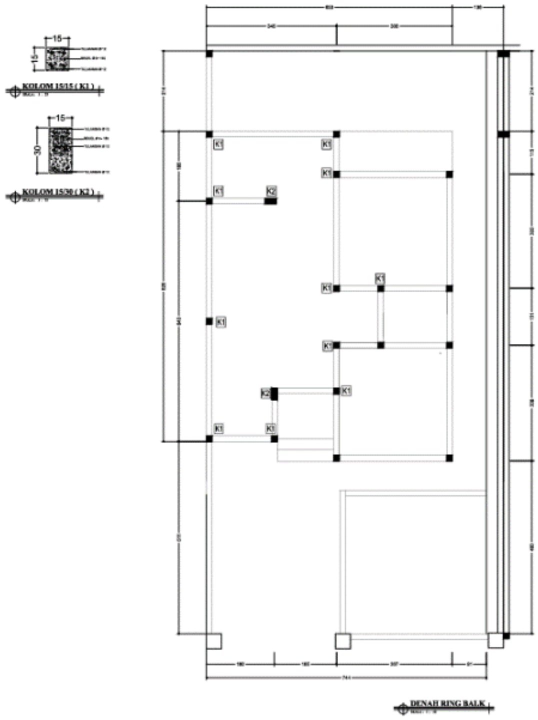

Figure 3 Column Structure Plan of Official Residence, Jl. Manukan Tengah
Source: Detailed Engineering Design (DED) Consultant, 2020

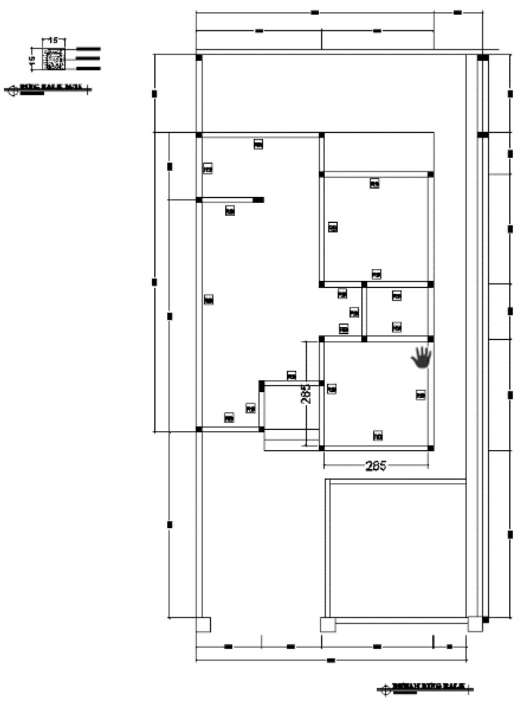

Figure 4 Beam Structure Plan of Official Residence, Jl. Manukan Tengah
Source: Detailed Engineering Design (DED) Consultant, 2020

The roof structure was another key component. The roofing system utilized a combination of reinforced concrete gables, CNP steel purlins, and galvalume battens and rafters. Clay roof tiles were selected as the covering material due to their high durability against tropical climates while contributing to thermal comfort. This design aligns with Aldhshan et al. (2021), who argue that combining modern and local materials enhances energy efficiency while preserving the architectural identity of the area.

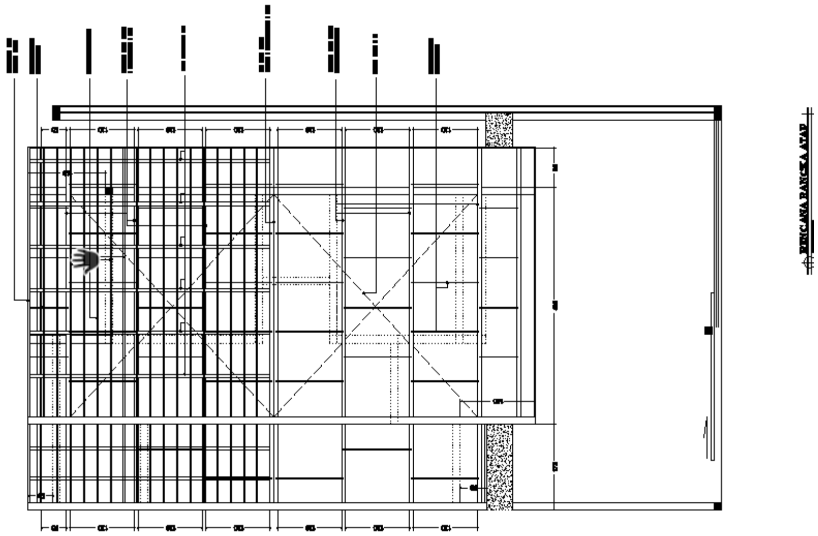

Figure 5 Roof Structure Plan of Official Residence, Jl. Manukan Tengah
Source: Detailed Engineering Design (DED) Consultant, 2020

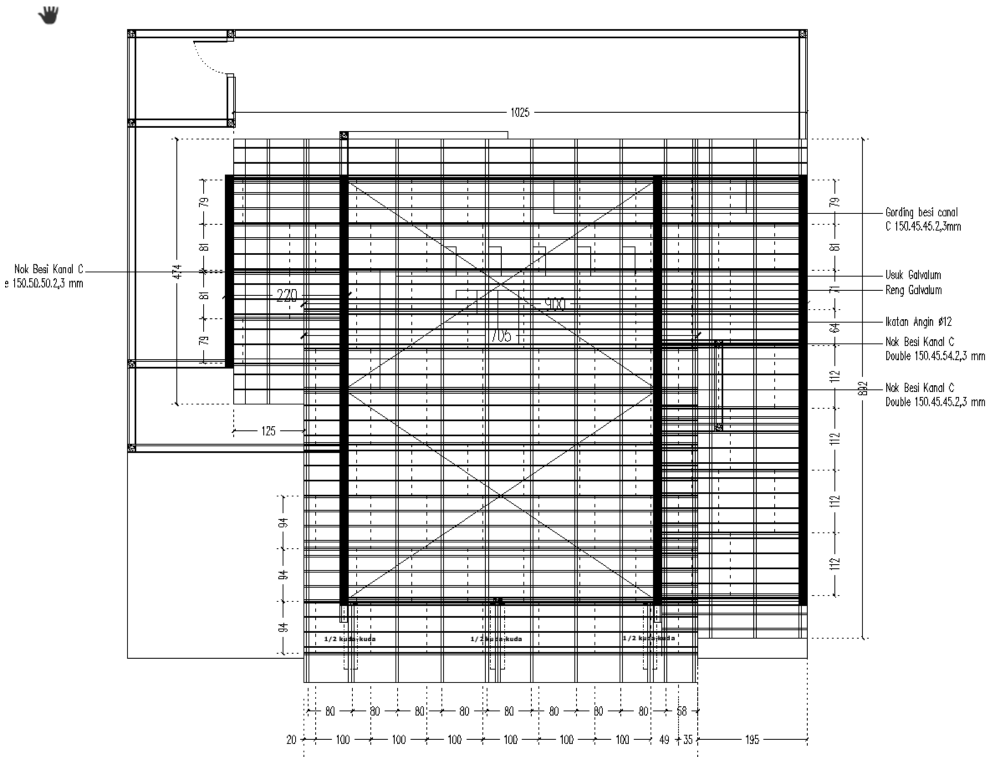

Figure 6 Roof Structure Plan of Official Residence, Jl. Mojoklanggru Lor
Source: Detailed Engineering Design (DED) Consultant, 2020

In addition to structural works, brick masonry, plastering, and finishing coats were carefully prepared. Red bricks were chosen due to their abundant availability in Surabaya, with a 1 PC:5 PS (Portland cement to sand) mortar mix. Plastering and finishing ensured that wall surfaces were smooth and ready for final finishing layers. The use of local materials was not only economical but also supported sustainability principles by reducing the carbon footprint associated with material transport. For ceilings, galvalume frames of 20x40 and 40x40 were used, combined with gypsum board in interior areas and calcium board in exterior areas. For flooring, polished and unpolished ceramic tiles of 40x40 and 25x40 dimensions were used according to functional needs. These material choices were made with consideration of durability, local market availability, and ease of maintenance.

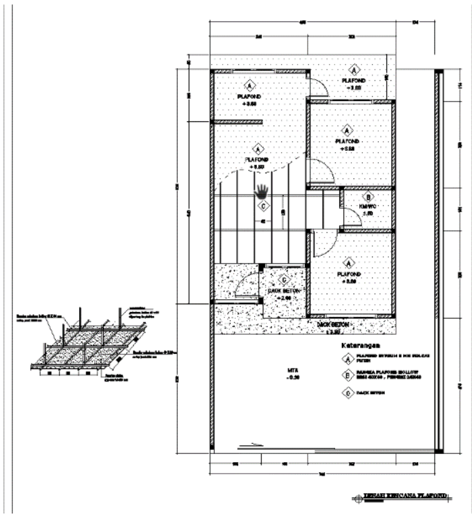

Figure 7 Ceiling Cover Plan of Official Residence, Jl. Manukan Tengah
Source: Detailed Engineering Design (DED) Consultant, 2020

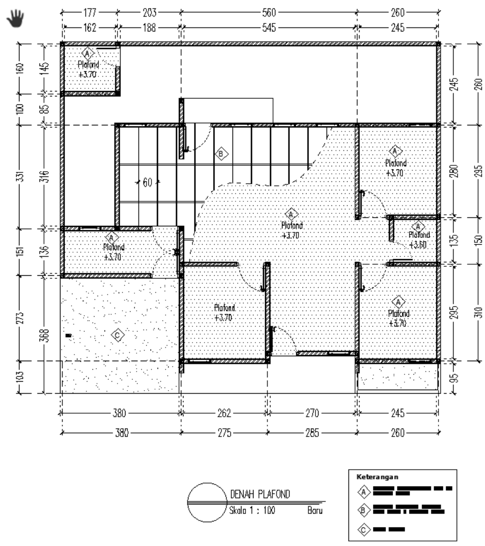

Figure 8 Ceiling Cover Plan of Official Residence, Jl. Mojoklanggru Lor
Source: Detailed Engineering Design (DED) Consultant, 2020

Finishing works, such as interior, exterior, and ceiling painting, were also meticulously planned. High-quality paints were specified, with weather-shield coatings for exteriors to protect against the humid and hot tropical climate. Appropriate finishing materials are essential, as they can extend building life while reducing future maintenance costs.

For MEP systems, planning was adjusted to the functional requirements of the official residences. Electrical installations were designed to be energy-efficient, incorporating LED lighting and efficient distribution systems. The clean water and sanitation systems used SNI-standard pipes resistant to pressure and corrosion. Well-planned MEP systems are indispensable for ensuring resident comfort.

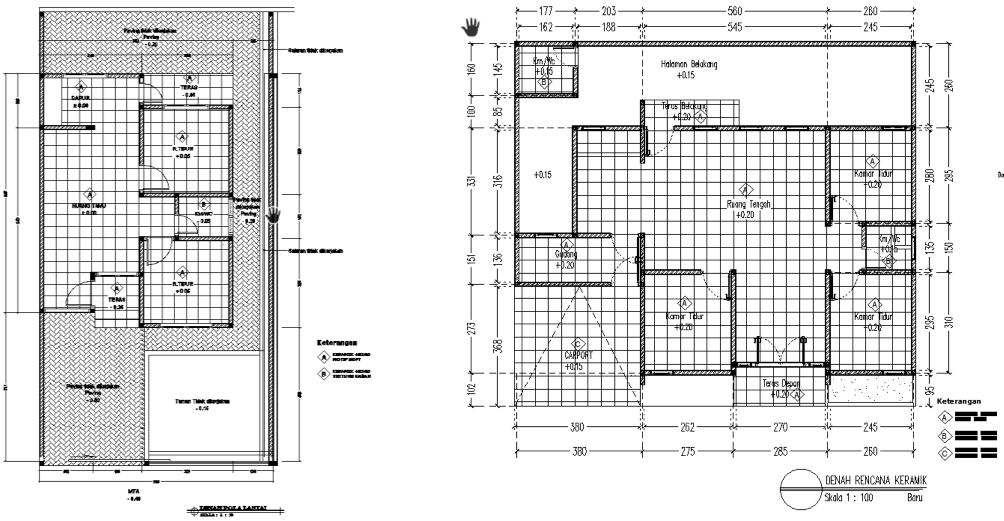

Figure 9 Ceiling Plan of Official Residences, Jl. Manukan Tengah and Jl. Mojoklanggru Lor
Source: DED Planning Consultant, 2020

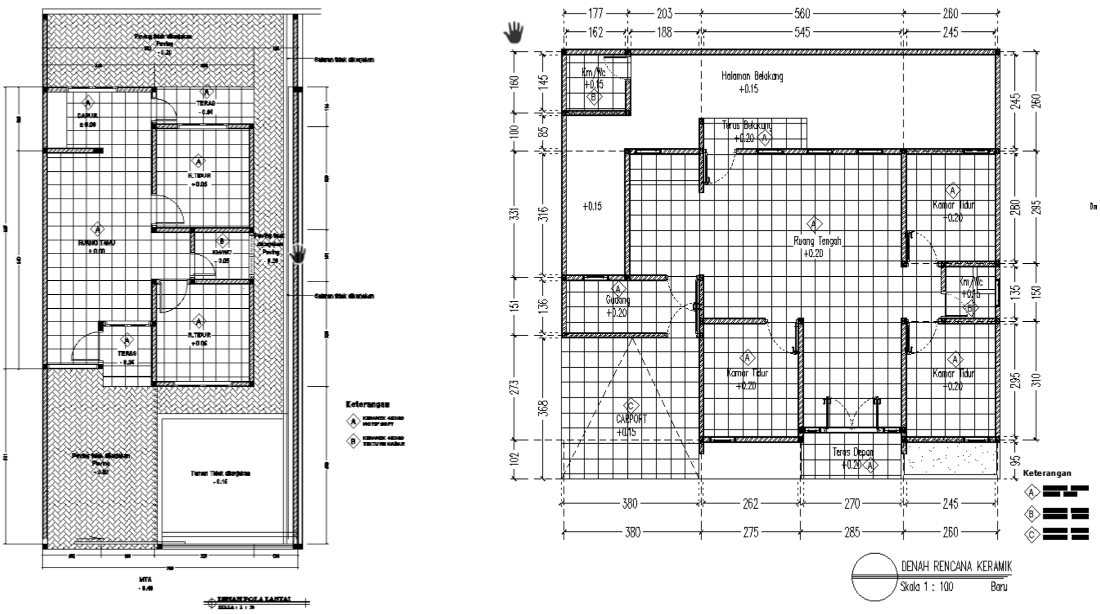

Figure 10 MEP Plan of Official Residences, Jl. Manukan Tengah and Jl. Mojoklanggru Lor
Source: DED Planning Consultant, 2020

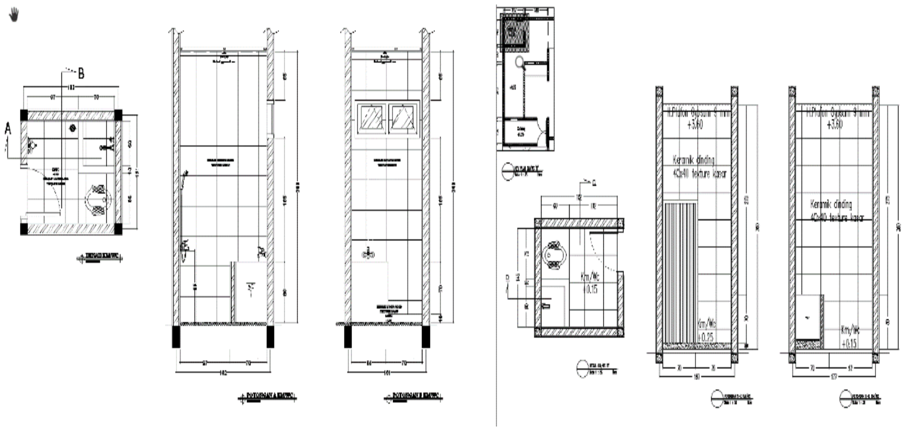

Figure 11 Sanitation Plan of Official Residences, Jl. Manukan Tengah and Jl. Mojoklanggru Lor

Source: DED Planning Consultant, 2020

The work schedule was prepared according to construction management principles, with structural works executed first, followed by architectural works and MEP installations. This approach applied the Critical Path Method (CPM) to identify tasks most critical to the overall project duration. Petroutsatou (2022) emphasizes that CPM-based management can improve time efficiency by up to 20% compared to conventional planning. With this approach, rehabilitation of the two official residences in Surabaya was estimated to be completed in 90 calendar days, with 40% of time allocated to structural works, 35% to architectural works, and 25% to MEP and finishing works. To provide measurable planning, the main material requirements were calculated based on the available working drawings. Material requirement data are presented below:

Table 1 Main Material Requirements for Official Residence Rehabilitation

Work Type	Main Material	Volume/Unit	Notes
Stone Foundation	Stone, cement, sand	12 m^3	For perimeter foundation
Column Structure	K-225 concrete, Ø12 reinforcement steel	8 m^3	Sizes 15/15 and 15/30
Roof Structure	CNP steel, galvalume, clay roof tiles	120 m^2	Combination of local & modern
Brick Masonry	Red bricks, cement, sand	110 m^2	Interior & exterior walls
Ceiling	Galvalume frame, gypsum & calcium board	95 m^2	Interior & exterior ceilings
Flooring	Ceramic tiles 40x40 and 25x40	85 m^2	Main interior areas
Exterior Painting	Weather-shield paint	180 m^2	Exterior walls
Interior Painting	Interior paint	160 m^2	Interior walls and ceilings

Source: DED Calculation Results, 2020

Rehabilitation Cost Analysis (RAB)

The rehabilitation cost analysis (Rencana Anggaran Biaya, RAB) represented a critical stage in construction project planning, as it relates to both sustainability and implementation effectiveness. In the case of official residence rehabilitation, the RAB served not only to identify funding needs but also as a control instrument to ensure the project remained within budget without compromising construction quality. The RAB preparation referred to the Indonesian National Standards (SNI) as the technical guideline, ensuring that each cost component corresponded to applicable unit prices, volumes, and work specifications.

Based on the technical data prepared, the cost analysis revealed that the rehabilitation of the two residences, one located on Jl. Manukan Tengah and the other on Jl. Mojoklanggru Lor, required IDR 281,202,000 and IDR 283,904,000, respectively. These figures serve as crucial benchmarks in assessing the financial feasibility of the rehabilitation project.

The detailed RAB was based on work components encompassing structural, architectural, MEP, and finishing works. Each component was calculated according to applicable unit prices in the field as set by SNI. For example, foundation works, whether stone masonry or pilecap, were calculated based on excavation volume, masonry material, and required labor, multiplied by the unit price. The same principle applied to sloof, columns, beams, roofing, brick masonry, plastering, ceilings, flooring, painting, MEP, and sanitation works. All cost requirements were systematically consolidated into a recap table to facilitate analysis of the total budget.

Table 2 Rehabilitation Cost Recapitulation of Official Residences

Official Residence Location	Total Cost (IDR)	Notes
Jl. Manukan Tengah	281,202,000	Based on detailed RAB SNI 2020
Jl. Mojoklanggru Lor	283,904,000	Based on detailed RAB SNI 2020
Total Budget	565,106,000	Rehabilitation of two units

Source: DED Data from Planning Consultants (2020), processed by the author

The table shows that the total budget required for the two residences amounted to IDR 565,106,000. This figure was still within the allocated budget capacity, indicating that the rehabilitation project could be implemented with a relatively high degree of certainty. This also demonstrates that the planning process was carried out carefully, taking into account all aspects of work requirements.

However, cost analysis for rehabilitation cannot stop a initial cost calculations alone. The concept of life cycle cost (LCC) is a critical aspect to consider. LCC is a cost analysis approach that not only considers initial construction expenses but also includes operating, maintenance, repair, and demolition costs (Meena et al., 2022). This ensures financial sustainability of the project, as asset owners account not only for upfront funding but also for long-term maintenance budgets. Winata & Gultom (2024) similarly stress that public construction projects, including official residence rehabilitation, must be planned with a financial sustainability approach. Projects that prioritize only initial cost efficiency often face higher financial burdens in the future due to expensive maintenance needs. Conversely, when LCC is incorporated from the outset, owners can make more accurate financial projections, particularly in terms of energy savings, material upkeep, and structural durability.

In this rehabilitation project, LCC considerations are evident in material selection. Roofing materials such as galvalume and clay tiles, although requiring certain upfront costs, significantly reduce maintenance expenses due to their superior durability against weather. Similarly, galvalume ceiling frames, being termite-resistant, help reduce long-term maintenance costs compared to timber alternatives. This approach aligns with Rohman (2021), who emphasizes integrating construction planning with energy efficiency and material sustainability.

Energy efficiency also plays a vital role in LCC. Properly designed ventilation, lighting, and sanitation systems lower operational costs, particularly electricity and water expenses. Puspita & Patriotika (2021) found that investment in energy-efficient technologies during the construction phase reduces building operational costs by 20–30% over its service life. Thus, although initial costs may appear higher, the long-term financial benefits are more significant.

More broadly, applying LCC in official residence rehabilitation projects has implications for accountability in state budget management. Abduh et al. (2023) argue that one major cause of inefficiency in Indonesian public construction projects is the lack of long-term cost planning. Therefore, LCC is not merely a technical approach but also a component of good governance in public asset management.

From this perspective, the RAB of IDR 281,202,000 for the residence on Jl. Manukan Tengah and IDR 283,904,000 for the residence on Jl. Mojoklanggru Lor represents more than funding requirements. The budget should be regarded as a long-term investment with direct impacts on resident quality of life, asset sustainability, and efficiency in government expenditure. By integrating detailed cost estimates based on SNI with the life cycle cost approach, this rehabilitation project is not only a physical intervention but also a model for more sustainability-oriented development planning.

Integration of Sustainable Design Strategies

The integration of sustainable design strategies in the rehabilitation of official residences is not merely an aesthetic addition or technical innovation, but rather a fundamental approach to creating efficient, healthy, and environmentally friendly buildings. In the context of official residences located in tropical regions such as Indonesia, passive design strategies play a crucial role. These strategies emphasize the utilization of natural conditions, such as sunlight, wind direction, and humidity, to reduce dependency on artificial energy. Thus, sustainable design not only contributes to occupant comfort but also reduces the operational costs of the residence in the long term.

One of the primary elements is the utilization of natural lighting. The rehabilitation design is directed so that the official residences have sufficiently wide openings and strategically oriented windows, allowing sunlight to penetrate the interior optimally from morning to afternoon. Proper natural lighting reduces the need for artificial lighting during the day, thereby lowering electricity consumption. Moreover, natural light has been proven to improve occupant health, particularly by supporting the body's circadian rhythm, which influences sleep patterns and productivity (Bigwanto et al., 2024). In a simple simulation conducted on the rehabilitation design, it is estimated that daytime lighting needs can be reduced by up to 50%, indicating significant potential for energy savings.

In addition to lighting, cross ventilation is also a key focus in the rehabilitation design. Cross ventilation works on the principle of having two openings on opposite sides, allowing fresh air to flow in and hot air to exit. In humid tropical climates, this strategy is highly effective in reducing indoor temperatures without fully relying on air conditioning (AC). According to Roestamy et al. (2022), the application of passive design strategies such as cross ventilation can reduce cooling energy demand by up to 30% in tropical buildings. This aligns with the rehabilitation efforts for the official residences on Jalan Manukan Tengah and Jalan Mojoklanggru Lor, where the placement of windows, doors, and upper vents was redesigned to enhance natural air circulation. A simple observational calculation shows that indoor temperatures can be lowered by 2–3°C compared to buildings without cross ventilation.

Another important aspect of sustainable design is the selection of environmentally friendly local materials. Materials such as bricks, locally sourced wood with legal certification (SVLK), and clay roof tiles are chosen because they have a lower carbon footprint compared to imported or synthetic materials. The use of local materials also supports the surrounding economy, fostering a connection between the rehabilitation project and social sustainability. For example, sourcing bricks from local producers not only reduces transportation and distribution costs but also generates positive economic impacts for the community. Sandhyavitri (2022) found that the use of local materials in construction can reduce carbon emissions while simultaneously strengthening community involvement in development.

In addition to materials, energy-saving systems are another key aspect. In the rehabilitation design of official residences, the use of energy-efficient LED lamps is combined with natural lighting, along with spatial layouts that promote more efficient air circulation. Although the application of solar panels has not yet been fully planned, it remains a long-term option to support energy sustainability in official residences. According to Adiasma et al. (2023), the use of renewable energy technologies at the household scale can reduce conventional energy consumption by 25–40%. In other words, the integration of energy-efficient systems is not merely about cost savings but also represents a contribution to climate change mitigation.

Furthermore, the integration of sustainable design has implications for occupant comfort. Homes with natural lighting and cross ventilation are not only more energy-efficient but also healthier, as proper air circulation reduces the risk of excess humidity and mold growth. This is consistent with findings by Yanita & Mochtar (2021), which state that good indoor air quality is directly related to respiratory health and occupant productivity. In the context of official residences, improving occupant comfort carries strategic importance because it supports the performance of employees who reside in these buildings.

The application of sustainable design strategies also reflects sustainability values in a broader sense, economic, social, and environmental. Economically, these strategies reduce long-term operational costs. Socially, the use of local materials fosters community involvement. Environmentally, energy savings represent a tangible contribution to reducing carbon emissions. Therefore, the integration of sustainable design in the rehabilitation of official residences is not merely a matter of building technology, but also a manifestation of concern for a greener and more sustainable future.

Balancing Technical, Financial, and Environmental Aspects

The balance among technical, financial, and environmental aspects in the rehabilitation of official residences is a critical point determining the long-term success of the project. For decades, public building construction and rehabilitation policies in Indonesia, including official residences, have tended to emphasize short-term cost efficiency. While this practice may deliver instant results in the form of quick project completion with controlled budgets, it often neglects technical and environmental factors. As a result, rehabilitated buildings frequently experience damage within only a few years, require high maintenance costs, and fail to meet occupant comfort standards. This narrow view of upfront costs must be corrected with a broader perspective that integrates technical, financial, and environmental sustainability into a single planning framework.

From a technical perspective, the rehabilitation of official residences must ensure that structural elements and materials used truly meet national quality and durability standards. Material selection, construction methods, and project management systems should not simply pursue rapid completion targets. In this study, technical evaluation was conducted through material quality tests and structural damage surveys, which revealed that the use of low-quality conventional materials actually shortened building lifespans. For instance, roofs lacking sufficient ventilation resulted in high humidity, accelerated corrosion of structural frames, and triggered additional repair costs. Therefore, the preparation of technical planning documents in rehabilitation must prioritize extending building lifespans, not merely restoring short-term physical functions.

However, strong technical foundations alone are insufficient without careful financial planning. Cost analysis in this study shows that the rehabilitation of the official residence on Jalan Manukan Tengah required Rp281,202,000, while the residence on Jalan Mojoklanggru Lor required Rp283,904,000. At first glance, these figures remain within reasonable limits and align with allocated budgets. However, financial planning that focuses solely on upfront expenditures risks long-term inefficiency. By contrast, applying life cycle cost analysis, which considers operational expenses, maintenance, and potential energy savings from sustainable design strategies, reveals that this rehabilitation project has the potential to become more financially efficient in the long run. Damayanti et al. (2021) emphasize that financial sustainability in construction can only be achieved if planning encompasses the entire building life cycle, not just initial investment. In other words, although upfront costs may be slightly higher when using environmentally friendly materials or energy-efficient systems, the long-term economic benefits are far more significant.

Meanwhile, environmental aspects should not be regarded as additional burdens but as integral components of quality rehabilitation. Official residences, as public facilities, carry strategic functions, not only as dwellings but also as symbols of government commitment to sustainable development. The integration of sustainable design in this rehabilitation project, such as the use of natural lighting, cross ventilation, and environmentally friendly local materials, has been shown to reduce energy consumption and decrease the building's carbon footprint. Arumsari & Rarasati (2017) found that passive design strategies in tropical buildings can reduce energy consumption by up to 30%. This means that by optimizing natural lighting and cross ventilation, official residences become not only more comfortable but also more energy-efficient. These findings are highly relevant to major Indonesian cities, including Surabaya, which face increasing pressures from rising energy consumption and urban environmental degradation.

Balancing these three aspects creates mutually reinforcing synergies. Robust technical approaches ensure that rehabilitation yields durable and long-lasting outcomes. Financial analysis based on life cycle costing guarantees that projects do not strain long-term budgets but instead become profitable investments. At the same time, integrating environmental considerations not only addresses global sustainability challenges but also enhances occupant comfort in official residences. Hamit et al. (2023) found that public construction projects integrating these three aspects are more resilient while simultaneously reducing urban carbon emissions. These findings affirm that the success of official residence rehabilitation should not be measured solely by how quickly projects are completed or how low the initial costs are, but rather by their overall impact on improving occupant quality of life while preserving environmental sustainability.

CONCLUSION

The findings of this study confirm that the rehabilitation of official residences in Surabaya can no longer be viewed solely from the perspective of short-term cost efficiency but must instead be implemented through an integrative approach that combines measurable construction planning, life cycle cost analysis, and sustainable design strategies. The results demonstrate that the application of passive design through natural lighting, cross ventilation, environmentally friendly local materials, and the potential for energy-efficient systems improves occupant comfort, extends building lifespans, and reduces long-term operational costs. Thus, the rehabilitation model proposed in this study addresses the need for government housing that is more resilient, efficient, and environmentally friendly, while also introducing a holistic approach that has rarely been applied in the context of official residence rehabilitation in Indonesia. These findings not only provide practical contributions to the management of government housing but also offer novelty to the civil engineering and environmental engineering literature by demonstrating that balancing technical, financial, and environmental aspects is a prerequisite for sustainable management of official residences.

ETHICAL STATEMENT AND DISCLOSURE

This study was conducted in accordance with established ethical principles, including informed consent, protection of informants' confidentiality, and respect for local cultural values. Special consideration was given to participants from vulnerable groups to ensure their safety, comfort, and equal rights to participate. No external funding was received, and the authors declare no conflict of interest. All data and information presented were collected through valid research methods and have been verified to ensure their accuracy and reliability. The use of artificial intelligence (AI) was limited to technical assistance for writing and language editing, without influencing the scientific substance of the work. The authors express their gratitude to the informants for their valuable insights, and to the anonymous reviewers for their constructive feedback on an earlier version of this manuscript. The authors take full responsibility for the content and conclusions of this article.

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