

Quantitative Study on Iron Reinforcement Waste Utilization for Material Efficiency in Boarding House Structures in Bantul

Rizal Maulana^{1✉}, Sely Novita Sari²

^{1,2} Civil Engineering Study Program, Faculty of Engineering and Planning, Institut Teknologi Nasional Yogyakarta (ITNY), Indonesia

✉ **Corresponding Author** : Rizal Maulana (e-mail: rizalmaulana@itny.ac.id)

Article Information	ABSTRACT
Article History Received : September 18, 2025 Revised : October 01, 2025 Published : October 04, 2025	The construction sector is one of the largest consumers of material resources, with reinforcement bars (rebar) contributing significantly to project costs. However, standard cutting practices often generate leftover steel, typically regarded as waste, despite its potential for reuse. This study aims to evaluate the efficiency of reusing rebar waste in the structural components columns, beams, and slabs of a two-story boarding house project in Bantul, Indonesia. A quantitative case study method was applied, analyzing planned versus actual steel usage, and calculating the waste percentage compared to the 5% standard from Indonesia's AHSP. Field data, including drawings, BoQ, and technical reports, were used to measure actual rebar waste and its financial impact. Results show actual waste levels of 2.17% for columns, 2.55% for beams, and 1.21% for slabs significantly lower than the 5% benchmark. This translates into a cost saving of Rp11,393,643.78 for a medium-scale project. These findings confirm that precise planning and reuse of steel offcuts can minimize waste and promote sustainable construction practices. It is recommended that future projects adopt material reuse strategies and integrate digital tools such as BIM to enhance real-time material tracking and cutting optimization.
Keywords: <i>Construction Waste; Rebar Efficiency; Sustainable Construction; Material Reuse.</i>	

INTRODUCTION

The construction sector is one of the largest contributors to the use of material resources, with more than 50% of project costs allocated to the purchase of building materials (Formoso et al., 2002). One of the main components in reinforced concrete structures is reinforcing iron, which has a significant contribution to the total cost of the project. In practice, cutting reinforcing iron in the field often results in residual material (waste) because the standard bar length does not always correspond to the actual needs of the structure (Kgathi & Bolaane, 2001). Unfortunately, this residue is often considered waste, when it can still be used for other structural components if planned properly.

The main problem that often occurs in construction projects is the waste of materials due to the remaining unused pieces (Bossink & Brouwers, 1996). In ironing work, this happens due to a lack of planning for cutting and remanaging residual material. This waste has a direct impact on rising costs and decreasing project efficiency (Kusuma, 2010). One of the solutions that can be applied is to optimize the need for repetition with a quantitative approach, so that the remaining iron can be reused for other structural elements that are still in accordance with the design specifications.

Research on material efficiency in construction, particularly the reuse of reinforcing iron waste, has shown significant results in various international studies. (Widjaja & Kim, 2023) developed a two-stage algorithm that is able to reduce the cutting waste of reinforcing iron to almost zero and result in material savings of up to 12.31% per project. On the other hand, the addition of waste metals to concrete mixtures has been shown to improve mechanical performance, which records an increase in compressive strength of 42.2% with the addition of 8% steel powder (Castillo Jaramillo & Uría Lara, 2025) and the results recorded an increase in tensile strength of up to 29% through the use of recycled steel fibers (Hussein & Abbas, 2023). Advanced applications in composite systems and structural panels also demonstrate excellence in bearing capacity and resistance to seismic loads (Alfeehan et al., 2020; Lisicins et al., 2024; Liu et al., 2024).

Despite this, most of these studies are still limited to laboratory scenarios or large-scale projects with adequate research infrastructure. Very few studies have directly measured and analyzed actual reinforcing iron residue in small-to-medium construction projects, such as two-story boarding houses in developing areas. In fact, this sector accounts for a large portion of development in areas such as Bantul, with the potential for significant economic and environmental impacts (Hertwich et al., 2019). In addition, quantitative comparisons between waste estimates based on national standards (AHSP 5%) and actual field data, as well as their conversion into measurable forms of cost efficiency, have not been widely raised in the local construction literature (ZA et al., 2023).

Departing from the existing research gap, this study presents a novelty in the form of a quantitative analysis of actual waste of reinforcing iron on the structural elements of columns, beams, and plates in a two-storey boarding house building project in Bantul. Unlike the previous approach which was simulative or laboratory-based, this study directly used field data to compare the level of efficiency of material use to the standard of Unit Price Analysis (AHSP), which assumes waste of 5%. The difference between the actual and standard numbers is then converted into potential cost savings based on the applicable unit price of materials, resulting in concrete and applicable efficiency measures (Hermawan et al., 2023).

More than just data analysis, this study also applies the reuse material approach directly in the field, making it both technically and contextually relevant. Thus, this study bridges the technical findings of various international research related to the optimization and utilization of reinforced iron waste with real practices in small-medium scale local projects. The results of this research are expected to make a real contribution in reducing material waste, streamlining budgets, and supporting the implementation of green construction strategies in the context of more sustainable development. In particular, this study aims to analyze the efficiency of the use of residual reinforcing iron in the structural elements of columns, beams, and plates, through a comparison between actual waste in the field and the standard waste according to the 5% AHSP, as well as calculating the economic impact in the form of potential cost savings resulting from optimizing the cutting and reuse of materials in small-medium scale construction projects. This effort is not only important in the context of project cost control, but also has a significant environmental impact.

Efficiency in the use of materials in construction projects is not only a matter of budget savings, but also closely related to reducing the volume of construction waste that often pollutes the environment around the project (Laovisutthichai et al., 2022). In the framework of sustainable development, the reuse of residual materials is one of the main pillars that support resource efficiency and waste management. Therefore, this research has a high urgency not only as a technical solution, but also as a contribution to more economically and ecologically responsible construction practices.

RESEARCH METHODS

This study uses a descriptive quantitative approach with a case study method, which aims to evaluate the efficiency of the utilization of residual reinforcing iron in a two-storey exclusive

boarding house building project located in Bantul, Special Region of Yogyakarta. This approach was chosen because it is able to present numerical data that can be calculated, compared, and analyzed objectively to measure actual performance against material efficiency standards (Weyant, 2022).

The research design is in the form of a comparative analysis between the planned volume, the actual volume of reinforcement iron use, and the volume of waste that occurs in the field. The research location was determined by purposive sampling, namely on one project that has been completed and uses a conventional reinforced concrete structure system. The selection of this project was based on the availability of complete technical data such as working drawings, actual volumes of execution, and documentation of iron cutting in the field. The population in this study is all the main structural components that use reinforcing iron, namely columns, beams, and floor plates. The sampling technique is carried out with a total sampling approach, because all structural units are relevant to be analyzed and the number is still affordable to be thoroughly evaluated (Waruwu, 2024).

The data in this study was collected through various project technical documents that support the overall analysis process. The main data sources include working drawings or Detailed Engineering Design (DED), Bill of Quantity (BoQ), actual data on the use of reinforcing iron in the field, and construction implementation documentation which includes technical reports and project evaluation results. These instruments are used in an integrated manner to calculate the planned volume of iron (according to DED), the actual volume installed in the field, and the volume of waste produced from the cutting and installation process in each structural element. The procedure for implementing the research was carried out systematically, starting from the identification of the need for reinforcing iron in each structural component, namely columns, beams, and plates, based on planning drawings. After that, the actual volume of iron consumption recorded in the project implementation report is calculated. From here, the remaining cut iron is collected, measured, and classified to determine whether it can still be reused or classified as waste. The next stage is to compare the actual waste yield with the national standard listed in the AHSP, which is 5%, to assess the level of efficiency in the use of materials and their impact on cost savings (Kgathi & Bolaane, 2001; Kristianto et al., 2020).

To support the quantitative analysis in this study, a mathematical calculation is needed that describes the relationship between the planned volume of reinforcing iron, the actual volume used, and the remaining material produced. The following formulas are used to calculate the actual waste percentage and material cost efficiency, which are the main indicators in assessing how much savings are achieved through the use of residual reinforcing iron. This approach aims to provide a clear and measurable picture of the impact of material management on project structure and budget efficiency. The formula used is as follows:

$$W\% = \left(\frac{V_s}{V_r} \right) \times 100 \quad (1)$$

$$Eb = (W_{AHSP} - W_{Actual}) \times V_r \times H \quad (2)$$

Variable Explanations

W%: Percentage of completed work volume (%).

Vs: Actual completed work volume (m³ or other relevant unit).

Vr: Planned or total work volume (m³ or other relevant unit).

Eb: Estimated cost difference (Rp).

W_{AHSP}: Unit price of work based on the Official Unit Price Analysis (AHSP) (Rp/unit).

W_{Actual}: Actual unit price of work in the field (Rp/unit).

H: Project duration/time (days, weeks, or months depending on context).

In this study, there are several important parameters observed. First, the total volume of the rebar iron according to the plan (V_r), which is the initial reference in the calculation of efficiency. Second, the actual volume of iron actually used in the field (V_a), which indicates the level of realization of material requirements. Third, the volume of residual reinforcing iron (V_s), which is the result of cutting iron rods that are not used but have the potential to be reused. Based on this data, the actual waste percentage ($W\%$) and cost efficiency (E_b) obtained from the difference between the actual volume and the standard estimate are calculated. All of these parameters are analyzed to illustrate the extent to which optimizing the use of residual reinforcing iron can provide technical and economic advantages in construction projects.

RESULTS AND DISCUSSION

Based on the data that has been collected from the construction project of an exclusive two-storey boarding house in Bantul, a series of calculations were carried out to determine the planned volume of reinforcing iron, the actual volume used in the field, and the volume of remaining unused iron. This analysis aims to measure the level of material efficiency through a comparison between the actual waste and the standard waste set in the AHSP of 5%. In addition, the potential cost savings that can be obtained from these efficiency are also calculated, as a basis for evaluating construction material management practices more effectively and economically.

Standard Drawing Structure

Standard structural drawings for repetition are engineering drawings that show the details, positions, and amounts of reinforcement on various structural elements such as foundations, columns, beams, floor plates, and walls. These drawings are made in accordance with applicable standards so that the repeats can be installed precisely as planned and ensure the strength and safety of the structure. This standard drawing drawing and guide is used as a reference in the calculation of reinforcement needs so that the calculation still pays attention to the needs of bend lengths, joints, and concrete blankets.

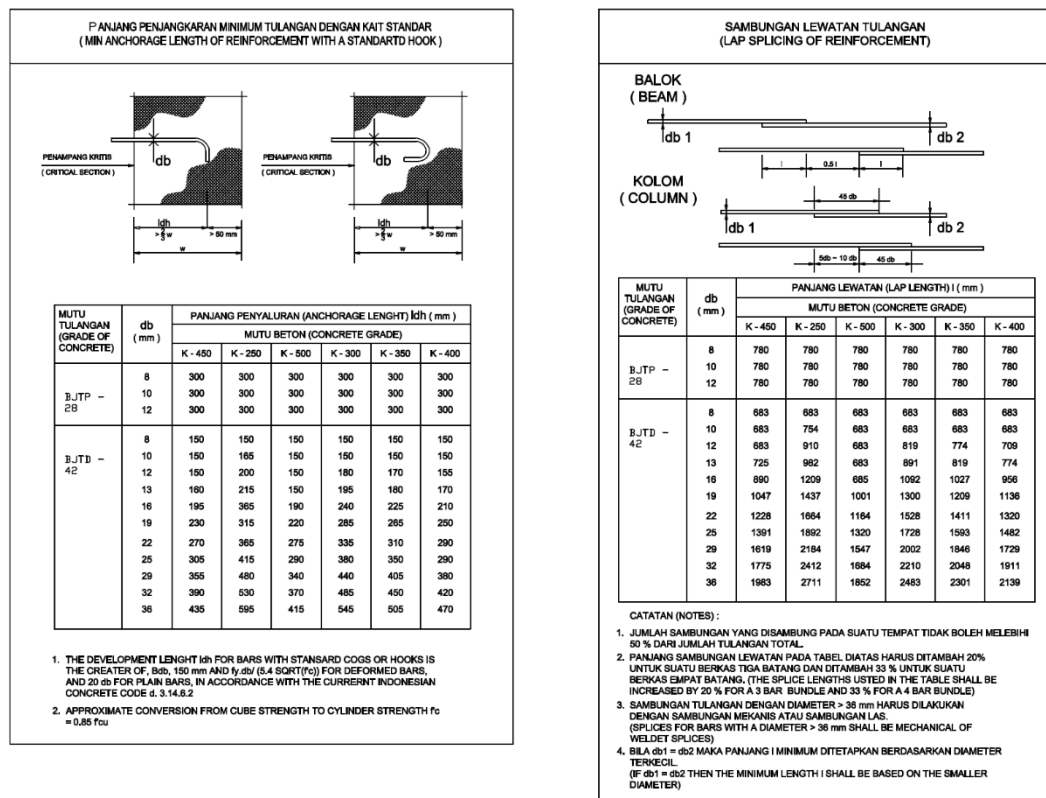


Figure 1. Standard Drawing Structure for Extension Length

Reinforcement Calculation

The calculation of reinforcement in the structure of a two-story boarding house includes three main elements, namely columns, beams, and floor plates. The column as the main vertical element functions to channel the load from above to the foundation, so the calculation is based on axial load analysis referring to SNI 2847 by considering the compressive strength of the concrete, cross-sectional area, and the need for the number and diameter of the reinforcement. The beam is designed to withstand bending moments due to horizontal and vertical loads, with calculations focusing on the maximum stress of the tensile reinforcement on the lower side and the compressive ability of the concrete on the upper side; The ratio of reinforcement to the cross-section of the concrete must be qualified for the collapse to be ductile. Meanwhile, floor plates that withstand even loads from occupants and furniture are designed as thin plates based on bending and deformation analysis, with loads calculated from dead and live loads which are then transformed into tensile reinforcement requirements at the bottom of the plates. The three calculations are carefully carried out to ensure that the structure is safe, efficient, and in accordance with applicable standards.

Waste and Cost Efficiency Calculation Results

In the two-storey exclusive boarding house building project in Bantul, the calculation of the volume of reinforced iron is carried out on three main elements of the structure: columns, beams, and plates. The results of measurements and recording in the field show that the volume of residual iron (cutting waste) in each element is different, but all of them **are below the 5% waste standard set in the Work Unit Price Analysis (AHSP)** by the Ministry of PUPR. For example, the calculation of the actual waste percentage on a column element can be written as follows:

$$W\%_{column} = \left(\frac{77,81}{3.585,62} \right) \times 100 = 2,17\%$$

Similar calculations are also performed for the elements of the beam and plate. For more information, the results of the calculation can be seen in Table 1.

Table 1. Actual Waste

Part	V _r /V _s	W% _{column}
Column	V _r =3.585,62kg V _s =77,81kg	2,17%
Beam	V _r = 4.225,86kg V _s = 107,81kg	2,55%
Plate	V _r =6.335,41kg V _s =76,89kg	1,21%

These results show that the **actual waste is entirely lower than the standard figure of 5%**, which indicates that there are fairly efficient material cutting and management practices in the field.

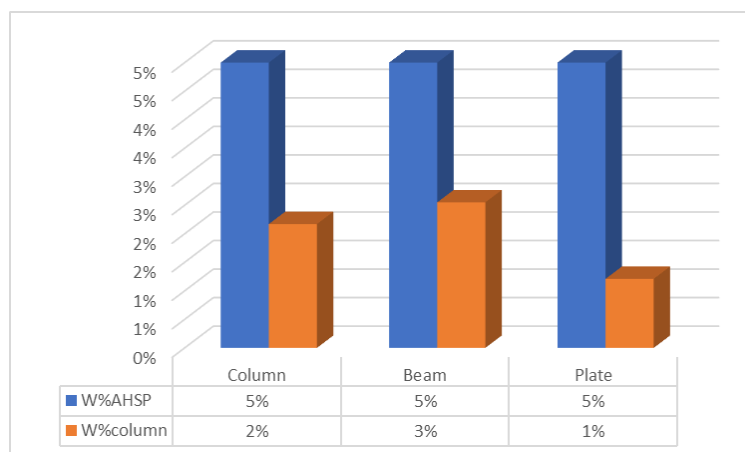


Figure 2. Comparison of Actual Waste and AHSP in Concrete Structures

Once it is known that the actual waste percentage is below the AHSP standard, the next step is to calculate the economic impact of the efficiency. This calculation is important to know how much cost savings can be achieved as a result of optimizing the utilization of residual reinforcing iron. By comparing the difference between the actual and standard waste percentages, as well as multiplying by the planned volume and the unit price of materials, it is possible to obtain a cost-efficiency value that demonstrates the financial benefits of more precise construction practices. For example, the calculation of cost efficiency in column elements is carried out using the standard waste value according to AHSP of 5% (0.05) and the unit price of reinforcing iron of Rp16,006.65 per kilogram.

$$Eb_{Column} = (0,05 - 0,217) \times 3.585,62 \times 16.006,65 = Rp2.426.655,18$$

Table 2. Cost Efficiency

Part	V _r /V _s
Column	Rp2.426.655,18
Beam	Rp2.587.877,40
Plate	Rp6.379.111,20
Total	Rp11.393.643,78

Thus, through optimizing the use of residual reinforcing iron in this project, it can save IDR 11,393,643.78 in one small-medium construction project. These savings seem simple, but when applied to hundreds of similar projects each year, the potential impact on national efficiency is significant. If, for example, this practice is applied to 100 similar projects per year, then the total efficiency achieved can reach more than Rp 1 billion nationally. This shows the importance of replanning the length of the iron cut and the utilization of internal waste of the project, as suggested in the study by (Formoso et al., 2002; Widjaja & Kim, 2023) on waste minimization in the construction industry.

The findings in this study are in line with the study conducted by (Widjaja & Kim, 2023), which shows that the optimization of the cutting process and rearrangement of reinforced iron can reduce waste to close to zero and result in material savings of 12.31% each project (Widjaja & Kim, 2023). This is reinforced that unused reinforcing iron waste still has a high technical value if reused, both as concrete reinforcing fibers and as additional ironing components in secondary structures (Hussein & Abbas, 2023). However, what distinguishes this study from previous studies is the context of its application. If previous research was mostly conducted in laboratory conditions or on large-scale projects, then this study proves that similar efficiencies can be achieved directly in the field, even on the scale of small-medium projects such as two-story boarding houses. With an actual data-driven approach from real construction projects, the results of this study make a more applicable and relevant contribution to local construction practices.

The material efficiency achieved also strengthens the position of material management as an integral part of the construction sustainability strategy. Material efficiency strategies are a highly effective approach in reducing the carbon footprint of the global construction industry (Hertwich et al., 2019). In addition, reducing construction waste not only has a positive impact on the environment, but can also cut project operational costs through reducing the volume of materials that must be disposed of (Bossink & Brouwers, 1996).

To further quantify the economic impact of efficient material usage, a comparative analysis was conducted between the reinforcement volumes based on AHSP standards and the actual field usage. This comparison provides insight into the cost savings achieved through reduced material waste. The detailed breakdown of cost efficiency for each structural element is presented in Table 2.

Table 2. Cost Efficiency of Reinforcement Work

Cost savings	AHSP	Field	efficiency	unit price	cost efficiency
Column	5,728.43	5,576.83	151.60	Rp 16,006.65	Rp2.426.655,18
Beam	7,117.29	6,955.62	161.68	Rp 16,006.65	Rp2.587.877,40
Plate	11,098.34	10,699.81	398.53	Rp 16,006.65	Rp6.379.111,20

The calculation results showed that the actual waste percentage of the three structural elements observed (columns, beams, and plates) was all below the 5% limit set by the AHSP. This indicates that the management of reinforcing iron in this project has been carried out efficiently. However, the strategic use of residual reinforcing iron for minor or secondary structures has not been maximized. This opens up the opportunity to construct a design module that optimally considers the length of the standard iron rod, so that the rest of the cut can be directly allocated to other elements in the same project. As a follow-up, these findings can encourage the development of a digital system based on a two-stage optimization algorithm, to minimize waste automatically and systematically (Widjaja & Kim, 2023). In addition, the integration of actual cutting data into the Building Information Modeling (BIM) platform can be a strategic step to improve the accuracy of estimating iron requirements and the effectiveness of reuse materials in real time in future projects.

Although it provided positive results, the study had a number of limitations. First, the scope of the study was limited to a single two-story boarding house project, so generalizations to projects of different scales, construction methods, or complexity should be done carefully. Second, this study has not evaluated the effect of residual iron utilization on structural performance, especially if it is reused in load-bearing elements. Third, human variables such as worker skills, cutting errors, and installation practices have not been quantitatively analyzed, even though these factors are very likely to affect the actual waste level in the field.

CONCLUSION

The results of the analysis show that the use of residual reinforcing iron in the structural elements of columns, beams, and plates can be carried out efficiently. The actual waste percentage in the column is 2.17%, the beam is 2.55%, and the plate is only 1.21%, all lower than the AHSP standard of 5%. The difference in efficiency has a direct impact on cost savings, which in this project reaches a total of Rp11,393,643.78. This value is quite significant, considering that the project analyzed is a small-medium scale construction. These findings confirm that with proper cutting planning and reuse of pieces of reinforcing iron, the potential for material waste can be minimized. This efficiency is not only economically beneficial, but also supports the principle of sustainable development through the reduction of construction waste.

As a recommendation, the practice of reusing materials needs to be adopted more widely in the implementation of construction projects, especially in similar projects that use reinforced concrete structure systems. This approach also needs to be supported by design modules and cutting methods that take into account the efficiency of the length of the stem. In the future, the integration of usage data and residual materials into digital systems such as Building Information Modeling (BIM) can improve the planning accuracy and effectiveness of material management in real time. The limitation of this study lies in the limited scope of the project. Therefore, it is necessary to conduct follow-up studies on other types of projects with different levels of complexity, including technical evaluations of the reuse of residual iron in secondary structural elements.

ACKNOWLEDGEMENTS

The researcher expressed his deepest gratitude to the Institute for Research, Community Service, and Innovation (LPPMI) of the Institut Teknologi Nasional Yogyakarta (ITNY) for funding support through the ITNY Research Fund for the 2023 Fiscal Year. This support has allowed this research to be carried out well until the final stage. Hopefully, the results of this research can make a real contribution to the development of science and construction practices that are more efficient and sustainable.

REFERENCES

- Alfeehan, A., Mohammed, M., Jasim, M., Fadehl, U., & Habeeb, F. (2020). Utilización de desechos metálicos industriales en los paneles de hormigón armado nervados unidireccionales. *Revista Ingeniería de Construcción*, 35(3), 246–256. <https://doi.org/10.4067/S0718-50732020000300246>
- Bossink, B. A. G., & Brouwers, H. J. H. (1996). Construction Waste: Quantification and Source Evaluation. *Journal of Construction Engineering and Management*, 122(1). [https://doi.org/10.1061/\(asce\)0733-9364\(1996\)122:1\(55\)](https://doi.org/10.1061/(asce)0733-9364(1996)122:1(55))
- Castillo Jaramillo, F. Y., & Uría Lara, E. R. (2025). Influencia de la incorporación de limaduras de acero en la resistencia a la compresión del concreto, Ayabaca, 2024. *Revista de Investigación Científica de La UNF – Aypate*, 3(4), 110–131. <https://doi.org/10.57063/ricay.v3i4.120>
- Formoso, C. T., Soibelman, L., De Cesare, C., & Isatto, E. L. (2002). Material Waste in Building Industry: Main Causes and Prevention. *Journal of Construction Engineering and Management*, 128(4). [https://doi.org/10.1061/\(asce\)0733-9364\(2002\)128:4\(316\)](https://doi.org/10.1061/(asce)0733-9364(2002)128:4(316))
- Hermawan, H., Aufa, M. A., & Arrizqi, A. N. (2023). PENGELOLAAN LIMBAH KONSTRUKSI PADA PROYEK PEMBANGUNAN HOTEL HORISON DIENG WONOSOBO. *Jurnal Ilmiah Arsitektur*, 13(2), 147–154. <https://doi.org/10.32699/jiars.v13i2.5607>
- Hertwich, E. G., Ali, S., Ciacci, L., Fishman, T., Heeren, N., Masanet, E., Asghari, F. N., Olivetti, E., Pauliuk, S., Tu, Q., & Wolfram, P. (2019). Material efficiency strategies to reducing greenhouse gas emissions associated with buildings, vehicles, and electronics—a review. *Environmental Research Letters*, 14(4), 043004. <https://doi.org/10.1088/1748-9326/ab0fe3>
- Hussein, O., & Abbas, A. (2023). Self-compacting Concrete Strengthening Efficiency Investigation by Using Recycled Steel Waste as Fibers. *Ecological Engineering & Environmental Technology*, 24(3), 153–160. <https://doi.org/10.12912/27197050/159790>
- Kgathi, D. L., & Bolaane, B. (2001). Instruments for sustainable solid waste management in Botswana. *Waste Management & Research: The Journal for a Sustainable Circular Economy*, 19(4), 342–353. <https://doi.org/10.1177/0734242X0101900411>
- Kristianto, M. A., Ajie, E. P., Hermawan, H., & Setiyadi, B. (2020). ANALISIS WASTE MATERIAL KONSTRUKSI PADA PEKERJAAN STRUKTUR ATAS BETON BERTULANG BANGUNAN TINGKAT TINGGI. *Jurnal Teknik Sipil*, 15(3), 143–149. <https://doi.org/10.24002/jts.v15i3.3727>
- Kusuma, V. A. (2010). Evaluasi Sisa Material Pada Proyek Gedung Pendidikan Dan Laboratorium 8 Lantai Fakultas Kedokteran UNS Tahap 1. *Skripsi*.

- Laovisutthichai, V., Lu, W., & Bao, Z. (2022). Design for construction waste minimization: guidelines and practice. *Architectural Engineering and Design Management*, 18(3), 279–298. <https://doi.org/10.1080/17452007.2020.1862043>
- Lisicins, M., Serdjaks, D., Akishin, P., Mironovs, V., Goremikins, V., & Lapkovskis, V. (2024). Improving the Structural Efficiency of Punched-Metal-Material-Based Composites. *Polymers*, 16(24), 3468. <https://doi.org/10.3390/polym16243468>
- Liu, B., Jiang, Y., Zhang, W., Yan, J., Xie, L., & Gurung, P. (2024). Enhancing performance and sustainability: CRB600H high-strength reinforcement in recycled concrete. *Sustainable Materials and Technologies*, 39, e00788. <https://doi.org/10.1016/j.susmat.2023.e00788>
- Waruwu, M. (2024). Metode Penelitian dan Pengembangan (R&D): Konsep, Jenis, Tahapan dan Kelebihan. *Jurnal Ilmiah Profesi Pendidikan*, 9(2), 1220–1230. <https://doi.org/10.29303/jipp.v9i2.2141>
- Weyant, E. (2022). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches, 5th Edition. *Journal of Electronic Resources in Medical Libraries*, 19(1–2), 54–55. <https://doi.org/10.1080/15424065.2022.2046231>
- Widjaja, D. D., & Kim, S. (2023). Reducing Rebar Cutting Waste and Rebar Usage of Beams: A Two-Stage Optimization Algorithm. *Buildings*, 13(9). <https://doi.org/10.3390/buildings13092279>
- ZA, T., Idris, S., Mohd Yusoff, M. Z., Siswanto, R., & Murziqin, R. (2023). Strategy on boarding school development: between trend and performance analysis. *Multidisciplinary Reviews*, 6(2), 2023013. <https://doi.org/10.31893/multirev.2023013>