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Contents

Analysis of SMK3 Implementation on Building Construction Project Implementation Performance (Case study of the Construction of the Menara Mandiri Building in Denpasar)

Made Sudiarsa a I Gede Sastra Wibawa b I Wayan Wiraga c I G A G Surya Negara Dwipa R S d I Wayan Arya e I Nengah Darma Susila

ABSTRACT

The construction industry is inherently associated with a high risk of occupational accidents. A major contributing factor to such incidents is the inadequate implementation of Occupational Safety and Health (OSH) practices. To mitigate these risks, the professional application of the Occupational Safety and Health Management System (OSHMS) is crucial and should comply with relevant laws and government regulations. This study aims to assess the level of OSHMS implementation in the construction of the Menara Mandiri Building in Denpasar and to identify key factors influencing its application. A qualitative descriptive method was employed, with data collected through the use of checklists and questionnaires. The data were analyzed using percentage analysis to determine the implementation level, descriptive statistics (mean values), and ranking analysis to identify influential factors. The findings indicate that the OSHMS implementation level was satisfactory, with a compliance rate of 96.39% and a minor noncompliance rate of 3.61%. The most significant factor influencing the implementation of OSHMS was the availability of occupational safety and health training for workers.

Keywords: construction project; implementation assessment; occupational safety and health; OSHMS; safety training;

1. INTRODUCTION

Construction is one of the sectors with a high risk of occupational accidents in Indonesia. The complexity of work processes, the diversity of the workforce, and the dynamic working environment make this sector vulnerable to various incidents that impact occupational safety and health (OHS) (Ismail et al., 2020). Therefore, the Indonesian government, through Government Regulation Number 50 of 2012, mandated the implementation of an Occupational Safety and Health Management System (SMK3) as a preventative measure to create a safe, efficient, and productive work environment.

SMK3 is an integral part of the overall company management system, aimed at controlling risks associated with work activities to create a safe and healthy workplace (Ministry of Manpower of the Republic of Indonesia, 2012). Effective SMK3 implementation is believed to improve project performance, both in terms of time, cost, quality, and worker safety in the field (Huda et al., 2021; Popov et al., 2010).In the context of building construction projects, the implementation of an OHSMS not only reduces the rate of workplace accidents but also contributes to increased operational efficiency and effectiveness. Previous studies have shown that construction projects that consistently implement OHSMS principles tend to have better project performance than projects that ignore them (Putra &

Ramli, 2019). However, various obstacles to OHSMS implementation in the field still exist, ranging from low management commitment, limited resources, to a lack of workforce awareness of the importance of OHS (Nugraha et al., 2022)

This study aims to analyze the extent to which OHSMS implementation impacts the performance of the Menara Mandiri Building construction project in Denpasar. This case study was chosen because it is a large-scale project located in an urban area with high work complexity. This analysis is expected to provide a comprehensive overview of the role of OHSMS in supporting the successful implementation of building construction projects and provide input for relevant parties in improving occupational safety and health management in the future (Liu et al., 2023).

2 Materials and Methods

This study uses a quantitative descriptive method to analyze the impact of the implementation of the Occupational Safety and Health Management System (SMK3) on the performance of building construction projects. This approach was chosen to describe and measure the extent to which SMK3 aspects are implemented and their impact on project performance indicators such as quality, cost, time, and occupational safety (Sugiyono, 2018)

Location and Research Objects

The research was conducted on the Menara Mandiri Building construction project located in Denpasar, Bali. This project was selected as a case study because it has complex construction characteristics and involves various types of occupational risks, making it relevant for analysis in the context of SMK3 implementation.

Data Collection Techniques

Data collection is done through two sources:

1. Primary Data: Obtained through questionnaires and direct interviews with respondents consisting of workers, project management, and OHS officers in the field. The questionnaire was compiled based on OHSMS implementation indicators following Government Regulation No. 50 of 2012.
2. Secondary Data: Obtained from project documents such as monthly project reports, work incident reports, as well as references from literature and previous research related to OHSMS and construction project performance (Creswell, 2014).

Data Analysis Techniques

The data obtained were analyzed using descriptive and inferential statistical methods. Descriptive statistical analysis was used to identify the level of OHSMS implementation and respondents' perceptions of project performance. Furthermore, to test the relationship between OHSMS implementation and project performance, Pearson correlation analysis and simple linear regression were used using SPSS software (Santoso, 2017). The research instrument was tested for validity and reliability before further analysis. Validity was measured by measuring the correlation between items in the questionnaire and the total score. Reliability was assessed using Cronbach's Alpha, with values above 0.70 considered reliable (Ghozali, 2016).

Population and Samples

The population in this study was all workers involved in the Menara Mandiri Building project. The sampling technique used was purposive sampling, selecting respondents deemed to have direct knowledge and experience in the implementation of the Occupational Health and Safety Management System (SMK3) and project performance. The number of respondents involved in this study was 40 people, consisting of foremen, supervisors, project managers, and OHS officers.

Testing Research Instruments

Validity Test

Validity testing using a statistical program (SPSS) has a significance value of 5% and uses a sample of 15 respondents, so the r-table value based on the table is 0.514. Each statement is compared with the r-table value, and the statement is declared valid if the r-table value is greater than the r-table value. Based on calculations using a statistical program (SPSS), the r-table value can be seen in the following table.

Table 1
Questionnaire Validity Test Results

X	N	r_{hitung}	r_{tabel}	information
X01	15	0.853	0.514	Valid
X02	15	0.621	0.514	Valid
X03	15	0.781	0.514	Valid
X04	15	0.781	0.514	Valid
X05	15	0.738	0.514	Valid
X06	15	0.537	0.514	Valid
X07	15	0.698	0.514	Valid
X08	15	0.711	0.514	Valid
X09	15	0.697	0.514	Valid
X10	15	0.625	0.514	Valid

Source: Analysis results, 2025

Based on the table above regarding the results of the validity test on the influencing factors of the implementation of the Occupational Safety and Health Management System (SMK3) in the Menara Mandiri Denpasar Building Construction project, it is clear that all the questions are valid because they have a correlation value above 0.514. Therefore, it can be said that these questions are suitable for use as a research questionnaire.

Reliability Test

The test was conducted using a Cronbach's Alpha value limit of 0.60. A research instrument can be considered reliable if the Cronbach's Alpha value is above 0.60. For more details, a reliability test of the factors influencing the implementation of the Occupational Safety and Health Management System (SMK3) in the construction of the Menara Mandiri Denpasar building is presented, as shown in the following table:

Table 1
Questionnaire Reliability Test Results

Reliability Statistics	
Cronbach's Alpha	N of Items
.884	10

Source: Hasil Analisa, 2025

Based on the table above regarding the results of reliability testing on factors influencing the implementation of the Occupational Safety and Health Management System (SMK3), it appears that all questionnaire items are reliable, as they have a Cronbach's alpha value above 0.60, namely 0.884. This indicates that all questionnaire items are suitable for use as measuring instruments in this study.

3 Results and Discussions

Analysis of SMK3 Implementation Level

Based on the results of the analysis and assessment of the checklist carried out, it is known that the number of fulfillments in the implementation of the 12 Criteria Elements consisting of 166 Sub-Criteria Elements contains 160 Criteria fulfilled/compliant and 6 Criteria not fulfilled/non-compliant (Minor Category), the results are then used to determine the percentage value of fulfillment of the achievement level based on the provisions stated in PP Number 50 of 2012 concerning the Implementation of the Occupational Safety and Health Management System (SMK3) by using the following calculation formula:

Achievement level: $\frac{160}{166}\ x\ 100\% = 96{,}39\%$

Degree of Nonconformity: $\frac{6}{166}\ x\ 100\% = 3.61\%$

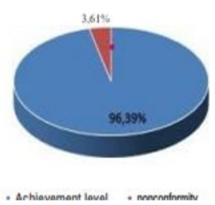

Figure 1. Results of Implementation Achievement Level

The results of the implementation achievement level based on the provisions of Government Regulation No. 50 of 2012, namely the implementation achievement level (85-100%), are considered Satisfactory. From the six non-conformities above, the core of the problems can be concluded as two main points:

1. Communication with workers, especially those providing information on OHS issues.
2. Installation of safety signs and hazard warnings.

From the above discrepancies, the following alternative solutions were obtained:

1. Based on the first core problem, namely communication with workers, especially regarding K3 issues, an alternative solution was taken with:

a) Worker representatives are maximally involved according to their role.

b) Increase routine consultations to boost worker enthusiasm and evaluate implementation.

c) Conduct outreach and outreach to increase OHS motivation and solicit input

d) Optimize the function of the Safety Officer, acting not only as a supervisor but also as a source of input from workers

2. Based on the second core problem, namely the installation of safety signs and hazard warnings, an alternative solution was taken:

a) Outreach and outreach to raise awareness of road signs among all parties.

b) Evaluating and improving the installation of road signs following regulations and guidelines.

c) Evaluating and improving site conditions and providing road signs that are appropriate to their condition and function

The distributed questionnaires were then reviewed to determine the results and answers from each respondent. The frequency of each response was then calculated. The calculated data was then analyzed to determine the mean value and ranking of each statement.

Descriptive Analysis

After collecting data from respondents, the data was analyzed using the mean method. The mean value is obtained by dividing the total data for all individuals in the group by the number of individuals. The results of the mean value calculation for each question are as follows:

Table 2
Average Value Analysis Results

Statistics		X01	X02	X03	X04	X05	X06	X07	X08	X09	X10
N	Valid	30	30	30	30	30	30	30	30	30	30
	Missing	0	0	0	0	0	0	0	0	0	0
Mean		3.77	3.70	3.63	3.60	3.47	3.47	3.50	3.60	3.53	3.30

Source: Hasil Analisa, 2025

Based on the descriptive analysis table above, the average (mean) value was obtained for all statements "Factors influencing the implementation of the Occupational Safety and Health Management System

Ranking Analysis

level of the samples based on a specific attribute. After obtaining the average value for all statements, a ranking test is performed by ordering the mean values from largest to smallest (Rokooei et al., 2023). The results of the ranking analysis can be seen in the following table

Table 3
Ranking Analysis Results

No	Factors influencing the implementation of the Occupational Safety and Health Management System	Mean	Ranking
1	Does the training on Occupational Safety and Health from the company where you work have an impact on implementation in the field?	3.77	1
2	Does the existence of a budget regarding K3 in construction projects have an impact on its implementation?	3.70	2
3	In your opinion, does using Personal Protective Equipment properly and correctly have an impact on workers in implementing Occupational Safety and Health?	3.63	3
4	If the company provides personal protective equipment for workers in this project, will this impact its implementation in the field?	3.60	4
5	Does the evaluation of the implemented K3 programs have an impact on the success of K3 implementation?	3.60	4
6	Can it have an impact on its implementation if the company imposes sanctions on workers who do not use Personal Protective Equipment?	3.53	5
7	Does the existence of a unit that handles K3 in the company where you work have an impact on the implementation of K3 in the field?	3.50	6
8	Does it matter if the project you are working on implements K3 following existing standards?	3.47	7
9	If the implementation of the Occupational Safety and Health Law has been carried out consistently, can it have an impact on the implementation of K3 in the field?	3.47	7
10	Will a safe and clean working environment have an impact on the implementation of K3 in the field?	3.30	8

From the analysis above, we obtain a ranking order for all statements. The ranking of factors influencing the implementation of the Occupational Safety and Health Management System in the Menara Mandiri Denpasar Building construction project shows that the most influential factor is Occupational Safety and Health training. The importance of OHS training is to equip, enhance, and develop workers OHS skills, typically covering work procedures and knowledge of hazards and their prevention. Even if workers have extensive experience, advanced skills, or work safely according to established procedures, this does not mean that workplace accidents or injuries are impossible (Sutapa et al., 2022).

4 Conclusion

Based on the results of the analysis, several conclusions can be drawn as follows:

1) The implementation level of the Occupational Safety and Health Management System (SMK3) in the Menara Mandiri Building Construction project in Denpasar showed a satisfactory level of

implementation, with a percentage of 96.39% compliance and 3.61% non-compliance (Minor Category). The non-compliance that resulted in the project not meeting the criteria of Government Regulation No. 50 of 2012 was communication with workers, specifically information on OHS issues, and the installation of safety signs and hazard warnings.

2) A factor influencing the implementation of the Occupational Safety and Health Management System (SMK3) in the Menara Mandiri Building Construction project in Denpasar was training on OHS. This training provided workers with knowledge of the hazards surrounding them and their prevention.

Conflict of interest stateme

The authors declared that they have no competing interests.

Statement of authorship

The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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References

Creswell, J. W. (2014). Research Design: Qualitative, Quantitative, and Mixed Methods Approaches (4th ed.). SAGE Publications.

Ghozali, I. (2016). Aplikasi Analisis Multivariate dengan Program IBM SPSS 23. Badan Penerbit Universitas Diponegoro.

Huda, M. A., Wibowo, M. A., & Purwanto, A. (2021). Pengaruh Penerapan Sistem Manajemen K3 terhadap Kinerja Proyek Konstruksi. Jurnal Karya Teknik Sipil, 10(2), 123-134.

Ismail, Z., Wahyuni, S., & Ramadhan, F. (2020). Analisis Risiko Kecelakaan Kerja pada Proyek Konstruksi Gedung Bertingkat. Jurnal Ilmiah Teknik Sipil, 24(1), 45-56.

Kementerian Ketenagakerjaan Republik Indonesia. (2012). Peraturan Pemerintah No. 50 Tahun 2012 tentang Penerapan Sistem Manajemen Keselamatan dan Kesehatan Kerja.

Kementerian Ketenagakerjaan Republik Indonesia. (2012). Peraturan Pemerintah No. 50 Tahun 2012 tentang Penerapan Sistem Manajemen Keselamatan dan Kesehatan Kerja.

Liu, R., Liu, H. C., Shi, H., & Gu, X. (2023). Occupational health and safety risk assessment: A systematic literature review methods, and applications. Safety science, 160, 106050. https://doi.org/10.1016/j.ssci.2022.106050

Nugraha, D., Lestari, N., & Maulana, A. (2022). Kendala Implementasi SMK3 pada Proyek Konstruksi di Indonesia. Jurnal Manajemen Proyek, 5(1), 67–76.

Popov, V., Juocevicius, V., Migilinskas, D., Ustinovichius, L., & Mikalauskas, S. (2010). The use of a virtual building design and construction model for developing an effective project concept in 5D environment. Automation in construction, 19(3), 357-367. https://doi.org/10.1016/j.autcon.2009.12.005

Putra, I. G. P., & Ramli, R. (2019). Penerapan Sistem Manajemen K3 terhadap Efektivitas Pelaksanaan Proyek Konstruksi di Kota Denpasar. Jurnal Teknik Sipil dan Lingkungan, 4(3), 145-154.

Rokooei, S., Shojaei, A., Alvanchi, A., Azad, R., & Didehvar, N. (2023). Virtual reality application for construction safety training. Safety science, 157, 105925. https://doi.org/10.1016/j.ssci.2022.105925

Sugiyono. (2018). Metode Penelitian Kuantitatif, Kualitatif, dan R&D. Alfabeta.

Sutapa, I. K., Yuni, N. K. S. E., Susila, I. N. D., Wibawa, . I. G. S., & Santiana, I. M. A. (2022). Evaluation of the implementation of occupational safety and health management systems on the ayana nort wing bali construction project. International Research Journal of Engineering, IT and Scientific Research, 8(1), 1–6. https://doi.org/10.21744/irjeis.v8n1.2034

Analysis Productivity and its Impact on Time and Cost of Implementation of the Private Residence Project Structure Work

I Made Budiadi a Ida Bagus Bintana b Made Suardana Kader c I Wayan Sudiasa d I Nyoman Ramia e I Nengah Darma Susila

A B S T R A C T

The construction project of Mrs. Tiya & Mr. Tom's Private Residence in Kemenuh-Gianyar is a 3-story villa development chosen as a case study due to discrepancies between the consultant's plans and the actual field conditions. This necessitated a method to optimize work completion. One proposed solution for accelerating the project was to add more workers. Based on the initial plan, the project required 104 days (3 months and 2 weeks) for completion, with a total structural work cost of Rp. 703,803,162.24. After analysis with the alternative of adding more workers, the project completion duration could return to the schedule of 90 days (3 months) or be accelerated by 12 days (2 weeks), with a total cost of Rp. 671,298,258.93. This concludes that adding more workers is an effective method to increase time efficiency by 14.29% and decrease costs by 4.6%, or the equivalent of Rp. 32,504,903.31

Keywords: cost; crash duration; human resources; project optimization; time;

1. INTRODUCTION

A construction project can be defined as a single-time activity within a specific timeframe, utilizing various resources. This means that effective utilization of available resources within a limited timeframe is necessary for a construction project to meet its objectives within specified time, cost, and quality constraints (Wibawa et al., 2023). Construction projects always require resources, namely: people, materials, machines, methods, money, management, information, and time. All of these resources are crucial to the success of a construction project. One solution to improve efficiency and achieve desired results is to increase labor productivity (Huemann et al., 2007). The first step every construction company must take is labor productivity planning to determine the performance of its workforce. The labor coefficient, or labor requirements per unit of work, is a multiplier in determining the number of workers and the unit price of wages (Rabbani et al., 2010). As a result, the difference between the total value and unit price of labor wages calculated in the budget and those used in the field can vary. In other words, whether a construction project will meet the established budget and schedule is greatly influenced by labor productivity (Thapa et al., 2024)As in the construction project of Mrs. Tiya & Mr. Tom's Private Residence in Kemenuh, Gianyar, in the Main Building area there were several differences between the consultant's plan drawings and the actual conditions in the field as well as the collapse of several excavations on the pile cap foundation caused by the intensity of rainfall which caused re-excavation in the affected area. With the owner's request that the completion time remain following the agreed schedule, this prompted the implementing contractor to make several revisions to the working

a) How much did the additional workforce change the implementation time for the structural work on the Mrs. Tiya & Mr. Tom Private Residence project in Kemenuh, Gianyar?

2 Materials and Methods

Location and Research Objects

Research on labor productivity and its impact on project costs and implementation time was conducted on the Mrs. Tiya & Mr. Tom Private Residence Development Project, Jln. Ir. Sutami, Kemenuh, Sukawati District, Gianyar Regency - Bal**i.**

Data Collection Techniques

To achieve the objectives of this research, clear data souces are required that align with the facts on the ground. These data sources are as follows.

: **1) Primary Data:** Primary data is data obtained directly by the author from the field using interviews and analysis of the construction project itself. This data will be used to calculate labor productivity and its impact on costs and implementation time. The following data is included in the primary data in this study:implementation time. The following data is included in the primary data in this study:

a) Work Time

b) Labor Costs

2) Secondary Data: Secondary data is data obtained by the author from other parties, in this case, the contractor for the Mrs. Tiya & Mr. Tom Private Residence Construction Project in Kemenuh, Gianyar, Bali. The following is included in the secondary data in this study:

a) RAB

b) AHSP (Work Unit Price Analysis)

c) Schedule (Time Schedule)

d) Working Drawings

e) Work Volume

f) Number of Workers

Variable Identification

1) Independent Variable

An independent variable is a variable that influences or causes changes in or the emergence of a dependent variable. The independent variable in this study is the productivity of labor use on the project

2) Dependent Variable

The dependent variable is a variable that is influenced or becomes a consequence of the presence of the independent variable. The dependent variables in this study are Cost and Implementation Time. The costs referred to are direct costs incurred in the actual project, while implementation time is the length of time required for labor to complete a project on the construction project of the Private Residence of Mrs. Tiya & Mr. Tom in Kemenuh, Gianyar, Bali.

Data Analysis

In analyzing human resource utilization against costs and implementation time delays due to inadequate working drawing planning, this research process focuses on calculating daily labor productivity to determine whether the results are in line with the agreed-upon schedule. This research must be conducted systematically, clearly, and orderly to achieve the desired results.

3 Results and Discussions

Primary Data

Primary data is data obtained by the author directly through interviews with foremen in the field. The primary data obtained by the author in this study include the wages of labor, including foremen, head craftsmen, masons, blacksmiths, carpenters, laborers, heavy equipment operators, overtime costs per hour, and the length of time required for each item reviewed.

Secondary Data

Secondary data that the author obtained from the Private Residence Development Project for Mrs. Tiya & Mr. Tom at Kemenuh, Gianyar, including:

1) Cost Budget Plan (RAB)

This Cost Budget Plan is necessary for the author to identify the work items to be executed and to determine the volume of work. The author will attach the Cost Budget Plan in Table 4.2. A summary of the Cost Budget Plan and the work reviewed in this research will be included in the appendix.

Material Control

After analyzing labor productivity and implementation time, the next step is to calculate the material requirements for each review work item to ensure that material requirements are in accordance with the plan. Material control in review work has the following calculation steps:

1) Find the volume of each work item by calculating data from the project plan drawings.
2) Find the duration of the work by calculating labor productivity for each work item.
3) Find the coefficient based on the AHSP used.
4) Calculate the amount of material required per day for each work item.

The following is an example of calculating iron requirements for Bore Pile reinforcement work:

Table 2
Daily Material Calculation

No	Work Items	Materials	Total Volume	Sat	Koef	Time	Daily Productivity	Sat	Daily Needs	Sat	Conversion	Sat
A.	Bore Pile Work											
1	Reinforcement Work	Iron D13	6448.78	Kg	0.681	9 days	758.29	Kg	516.55	Kg	42.00	btg
		Iron Ø10			0.319				241.74	Kg	33.00	btg
		Bendrat Wire			0.150				113.74	Kg	23.00	gl
2	Reinforcement Work	Ready Mix K-300	37.30	m³	1.020	7 days	5.92	m³	5.92	m³		

Cost Comparison

Based on the analysis, a comparison was obtained between the RAB (Cost Budget Plan) prepared during the project planning stage and the actual costs incurred in the field (Real Costs) during the project implementation. This comparison indicates differences or deviations that can be caused by various factors, such as wages and material prices that reflect local prices, as well as alternatives such as additional labor to meet previously planned deadlines. The following table shows the comparison between the planned RAB and the actual RAP in the field for the review work.

Table 3
Cost Comparison Between RAB and RAP

RAB			RAP		
No.	Work Items	Total price	No.	Work Items	Total price
A.	**Week 1**		**A.**	**Week 1**	
1	Bore Pile Drilling Pack	Rp 7,781,639.25	1	Bore Pile Drilling Pack	Rp 11,363,084.40
2	Bore Pile Supply Pack	Rp 42,458,024.64	2	Bore Pile Supply Pack	Rp 38,200,754.48
	Total	**Rp 50,239,663.89**		**Total**	**Rp 49,563,838.88**
B.	**Week 2**		**B.**	**Week 2**	
1	Bore Pile Drilling Pack	Rp 15,563,278.50	1	Bore Pile Drilling Pack	Rp 22,726,168.80
2	Bore Pile Supply Pack	Rp 42,458,024.64	2	Bore Pile Supply Pack	Rp 70,090,383.68
	Total	**Rp 58,021,303.14**		**Total**	**Rp 92,816,552.48**
C.	**Week 3**		**C.**	**Week 3**	
1	Bore Pile Drilling Package	Rp 12,969,398.75	1	Bore Pile Drilling Package	Rp 7,907,866.80
2	Bore Pile Reinforcement Package	Rp 35,442,975.27	2	Bore Pile Casting Package	Rp 51,697,800.00
3	Bore Pile Casting Package	Rp 26,810,769.70	3	Pile Cap Reinforcement Package PC1	Rp 9,779,952.00
4	Pile Cap PC2 Reinforcement Package	Rp 14,152,674.88	4	Pile Cap Reinforcement Package PC1.1	Rp 6,287,112.00
			5	Pile Cap Reinforcement Package PC2	Rp 19,100,461.20
	Total	**Rp 89,375,818.60**		**Total**	**Rp 94,773,192.00**

RAB			RAP		
No.	Work Items	Total price	No.	Work Items	Total price
D.	**Week 4**		**D.**	**Week 4**	
1	Bore Pile Drilling Package	Rp 6,821,699.50	1	Pile Cap Excavation PC1	Rp 4,533,300.00
2	Bore Pile Casting Package	Rp 26,241,840.90	2	Pile Cap Excavation PC1.1	Rp 2,914,100.00
3	Pile Cap Reinforcement Package PC1	Rp 10,869,822.80	3	Pile Cap Excavation PC2	Rp 10,046,400.00
4	Pile Cap Reinforcement Package PC1.1	Rp 6,987,743.23	4	Pile Cap Reinforcement PC2	Rp 27,182,523.53
5	Pile Cap Reinforcement Package PC2	Rp 21,229,012.32	5	Pedestal Column Reinforcement C1	Rp 19,868,953.17
			6	Pedestal Column Reinforcement C2	Rp 9,550,236.97
	Total	**Rp 72,150,118.76**		**Total**	**Rp 74,095,513.66**
E.	**Week 5**		**E.**	**Week 5**	
1	PC1 Pile Cap Excavation	Rp 3,436,438.50	1	Pile Cap Formwork Pack PC1	Rp 3,615,913.00
2	PC1.1 Pile Cap Excavation	Rp 2,209,014.50	2	Pile Cap Formwork Pack PC1.1	Rp 2,324,515.50
3	PC2 Pile Cap Excavation	Rp 5,397,876.00	3	Pile Cap Formwork Pack PC2	Rp 7,115,600.23
4	PC2 Pile Cap Reinforcement	Rp 16,059,039.99	4	Pedestal Column Formwork Pack C1	Rp 11,228,580.00
			5	Pedestal Column Reinforcement Pack C2	Rp 24,813,263.33
			6	Pedestal Column Formwork Pack C2	Rp 9,025,396.50
	Total	**Rp 27,102,368.99**		**Total**	**Rp 58,123,268.56**
F.	**Week 6**		**F.**	**Week 6**	
1	Pile Cap Formwork PC1	Rp 3,762,797.50	1	Pile Cap Casting Package PC1	Rp 11,232,375.00
2	Pile Cap Formwork PC1.1	Rp 2,418,941.25	2	Pile Cap Casting Package PC1.1	Rp 7,220,812.50
3	Pile Cap Excavation PC2	Rp 2,217,732.00	3	Pile Cap Casting Package PC2	Rp 31,713,225.00
4	Pile Cap Formwork PC2	Rp 7,404,647.94	4	Pedestal Column Casting Package C1	Rp 5,198,985.00
5	Pedestal Column Reinforcement C1	Rp 14,152,789.87	5	Pedestal Column Formwork Package C2	Rp 8,532,019.50
6	Pedestal Column Reinforcement C2	Rp 14,152,789.87	6	Pedestal Column Casting Package C2	Rp 6,021,720.00
			7	Excavation Package RS1	Rp 3,560,400.00
			8	Excavation Package RS2	Rp 3,560,400.00
	Total	**Rp 44,109,698.43**		**Total**	**Rp 77,039,937.00**
G.	**Week 7**		**G.**	**Week 7**	

RAB			RAP		
No.	Work Items	Total price	No.	Work Items	Total price
1	Pile Cap Casting Package PC1	Rp 11,380,292.00	1	Stone. Excavation RS1	Rp 2,469,510.00
2	Pile Cap Casting Package PC1.1	Rp 7,315,902.00	2	Stone. RS2 Excavation	Rp 7,678,320.00
3	Pile Cap Casting Package PC2	Rp 18,267,585.60	3	Stone. Couple Stone Times RS1	Rp 11,604,600.00
4	Pedestal Column Reinforcement Package C1	Rp 7,930,345.12	4	Stone. Couple Stone Times RS2	Rp 11,604,600.00
5	Pedestal Column Formwork Package C1	Rp 6,260,191.25			
6	Pedestal Column Reinforcement Package C2	Rp 24,040,154.14			
7	Pedestal Column Formwork Package C2	Rp 6,260,191.25			
	Total	**Rp 81,454,661.35**		**Total**	**Rp 33,357,030.00**
H.	**Week 8**		**H.**	**Week 8**	
1	Pile Cap Casting Package PC2	Rp 13,863,264.80	1	Stone. Couple Stone Times RS1	Rp 22,199,599.80
2	Pedestal Column Formwork Package C1	Rp 4,641,461.06	2	Stone. Couple Stone Times RS2	Rp 34,813,800.00
3	Pedestal Column Casting Package C1	Rp 5,267,449.44			
4	Pedestal Column Formwork Package C2	Rp 10,786,028.72			
5	Pedestal Column Casting Package C2	Rp 6,101,018.88			
6	Excavation Package RS1	Rp 2,698,938.00			
7	Excavation Package RS2	Rp 3,598,584.00			
	Total	**Rp 46,956,744.89**		**Total**	**Rp 57,013,399.80**
I.	**Week 9**		**I.**	**Week 9**	
1	RS1 Mining Pack	Rp 1,871,995.95	1	RS2 River Stone Masonry	Rp 18,555,755.40
2	RS1 Stone Installation Pack	Rp 12,375,000.00	2	Sloof Reinforcement Package S1	Rp 19,100,473.93
3	RS2 Mining Pack	Rp 4,920,854.40	3	Sloof Reinforcement Package S2	Rp 11,154,278.19
4	RS2 Stone Installation Pack	Rp 12,375,000.00	4	Sloof Reinforcement Package S3	Rp 12,237,097.77
	Total	**Rp 31,542,850.35**		**Total**	**Rp 61,047,605.29**
J.	**Week 10**		**J.**	**Week 10**	
1	Kali Stone Installation Kit RS1	Rp 23,673,375.00	1	Slope Reinforcement Package S1	Rp 19,635,457.52
2	Kali Stone Installation Kit RS2	Rp 37,125,000.00	2	Slope Excavation Package S1	Rp 2,628,900.00
			3	Slope Excavation Package S2	Rp 760,150.00
			4	Slope Excavation Package S3	Rp 872,850.00
	Total	**Rp 60,798,375.00**		**Total**	**Rp 23,897,357.52**

RAB			RAP		
No.	Work Items	Total price	No.	Work Items	Total price
K.	**Week 11**		**K.**	**Week 11**	
1	RS2 River Stone Installation Package	Rp 19,787,625.00	1	Pek. Formwork Sloof S1	Rp 12,057,507.00
2	Sloof Reinforcement Package S1	Rp 14,152,674.88	2	Pek. Formwork Sloof S2	Rp 3,921,063.30
3	Sloof Reinforcement Package S2	Rp 12,397,302.91	3	Pek. Formwork Sloof S3	Rp 3,603,010.95
4	Sloof Reinforcement Package S3	Rp 13,600,791.13			
	Total	**Rp 59,938,393.92**		**Total**	**Rp 19,581,581.25**
L.	**Week 12**		**L.**	**Week 12**	
1	Slope Excavation Site S1	Rp 28,899,960.86	1	Sloof Casting Package S1	Rp 18,526,125.00
2	Slope Reinforcement Site S1	Rp 1,992,820.50	2	Sloof Casting Package S2	Rp 4,819,710.00
3	Slope Excavation Site S2	Rp 576,226.75	3	Sloof Casting Package S3	Rp 6,643,147.50
4	Slope Excavation Site S3	Rp 661,658.25			
	Total	**Rp 32,130,666.36**		**Total**	**Rp 29,988,982.50**
M.	**Week 13**				
1	Pek. Formwork Sloof S1	Rp 12,067,984.50			
2	Pek. Formwork Sloof S2	Rp 3,924,470.55			
3	Pek. Formwork Sloof S3	Rp 3,606,141.83			
	Total	**Rp 19,598,596.88**			
N.	**Week 14**				
1	Sloof Casting Package S1	Rp 18,770,092.00			
2	Sloof Casting Package S2	Rp 4,883,179.84			
3	Sloof Casting Package S3	Rp 6,730,629.84			
	Total	**Rp 30,383,901.68**			
	Amount Total	**Rp 703,803,162.24**		**Amount Total**	**Rp 671,298,258.93**
Comparation					
Rp 32,504,903.31					

The table above compares the planned RAB and the actual RAP in the field for the reviewed work, based on the work completed per week. This comparison focuses solely on actual field expenditures. The analysis revealed that the RAP was lower than the RAB by approximately Rp. 32,504,903.31, or approximately 4.6%. This efficiency was achieved through the alternative of adding labor, which successfully accelerated the completion of the work, allowing the originally delayed implementation time to return to the planned schedul

4 Conclusion

From the results of the analysis of Labor Productivity and its Impact on Implementation Time and Costs for the Private Residence Project Structure Work, Kemenuh - Gianyar, the following conclusions can be drawn

1) Labor productivity on this project was still inefficient, resulting in work delays from the planned schedule. One of the tasks experiencing the greatest delay was bore pile drilling. With the addition of this workforce, work productivity increased significantly, from 31.75 m^1/day to 47.62 m^1/day

2) The addition of labor for structural work was proven to accelerate the project's implementation duration by 12 days, or approximately 2 weeks, compared to the previous delay. This acceleration allowed the project to return to its planned schedule. Thus, it successfully increased completion time efficiency by 14.29% compared to normal conditions.

3) The difference in the RAP value was Rp32,504,903.31, or approximately 4.6% of the RAB value, where this comparison only focused on material and labor costs due to the additional labor.

Conflict of interest statement

The authors declared that they have no competing interests.

Statement of authorship

The authors have a responsibility for the conception and design of the study. The authors have approved the final article.

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References

Apriliani, R. A., & Cahyono, B. N. (2023). Analisis Percepatan Proyek Dengan Menggunakan Metode Crashing. Narotama Jurnal Teknik Sipil, 7(1), 43-52

Asroni, A. (2010). Kolom Fondasi dan Balok T Beton Bertulang. Yogyakarta: Graha Ilmu. Herlina, N. (2017). Permasalahan lingkungan hidup dan penegakan hukum lingkungan di Indonesia. Jurnal Ilmiah Galuh Justisi, 3(2), 162-176.

Huemann, M., Keegan, A., & Turner, J. R. (2007). Human resource management in the project-oriented company: A review. International journal of project management, 25(3), 315-323. https://doi.org/10.1016/j.ijproman.2006.10.001

Jusmidah, J. (2016). Analisis Produktivitas Tenaga Kerja Pada Proyek Pekerjaan Jembatan Amassangan. PENA TEKNIK: Jurnal Ilmiah Ilmu-Ilmu Teknik, 1(1), 47-54.

Meivian, A. (2021). Perancangan Struktur Bawah Gedung Operasional Pt. Marga Mandalasakti Dengan Bored Pile. Jurnal Teknik Sipil Universitas Serang Raya, 1(1), 18-40.

Pohan, A. H., Indriasari, I., & Bangun, S. (2022). Metode pelaksanaan pekerjaan konstruksi struktur bawah pada perkantoran Danayasa Tower. Jurnal Teknik, 11(1).

Rabbani, M., Bajestani, M. A., & Khoshkhou, G. B. (2010). A multi-objective particle swarm optimization for project problem. Expert systems with applications, 37(1), 315-321. https://doi.org/10.1016/j.eswa.2009.05.056

Rompas, L. M. (2022). Analisis Proporsi Sumber Daya Pada Proyek Konstruksi (Studi Kasus Kota Manado). Tekno, 20(82), 1189-1194.

Saputra, H. (2019). Identifikasi Faktor-Faktor Yang Berpengaruh Terhadap Produktivitas Tenaga Kerja (Studi Kasus: Proyek Pembangunan Perumahan Mutiara Garuda, Panam Pekanbaru) (Doctoral dissertation, Universitas Islam Riau)

Siregar, H. K. A., Harahap, S., & Puspita, N. R. (2022). Analisa Perbandingan Nilai Harga Satuan

Pekerjaan (AHSP) Dengan Nilai Harga Standar Nasional Indonesia (Sni) Pada Pekerjaan Pembangunan Gedung/Ruang Baru Puskesmas Padangmatinggikota Padangsidimpuan. Statika, 5(1), 60-70

Thapa, D., Mishra, S., Velaga, N. R., & Patil, G. R. (2024). Advancing proactive crash prediction: A discretized duration approach for predicting crashes and severity. Accident Analysis & Prevention, 195, 107407. https://doi.org/10.1016/j.aap.2023.107407

Ujung, G. K. N. (2024). Perhitungan Pengendalian Bahan dan Tenaga Kerja Pekerjaan Struktur Proyek Pembangunan Villa 2 Bedroom Echo Beach Canggu (Doctoral dissertation, Politeknik Negeri Bali).

Wibawa, I. G. S., Santiana, I. M. A., Suasira, I. W., Sudiasa, I. W., & Sumardika, A. A. N. R. (2023). Risk analysis of material management that causes cost and time deviations in high-story building projects. International Research Journal of Engineering, https://doi.org/10.21744/irjeis.v9n6.2378 IT and Scientific Research, 9(6), 231–239

Combining Hydraulic Roughness Measurement Results with Manning's Roughness Coefficient in Drainage Channels (A Case Study of Drainage Channels in Denpasar City, Bali Province)

I Wayan Suparta a

A B S T R A C T

To measure its reliability, the quality of work and materials should be assessed using objective tools and methods. For example, concrete quality is measured using tools and methods of compression testing or a hammer test tool; the results are expressed in terms of characteristic compressive strength (f'c). Steel quality is determined by the tensile test method, and the quality or strength is expressed in tensile strength (fy). The quality of the highway surface is determined by the roughness test method using the NAASRA roughness meter and the results are expressed with good, moderate and poor criteria, correlated with the International Roughness Index (IRI) value, namely good roughness if the IRI value is <75 inches/mile, moderate for IRI values between 70-170 inches/mile and poor IRI > 170 inches/mile. The hydraulic quality of the drainage channel surface to date cannot be determined with objective tools and methods. Similar to the quality of the road surface, the hydraulic quality of the channel is also determined based on the criteria: good, moderate/normal, and poor, correlated with the Manning roughness coefficient; the difference is that there is no objective value for the good, moderate, and poor criteria. The hydraulic quality of the drainage channel is one of the most important factors in determining the capacity of the channel cross-section. This study aims to determine the hydraulic quality of the channel surface objectively by combining the measurement results with the value criteria and their relationship with the Manning roughness coefficient value that has been used so far. In this case, hydraulic roughness (Hr) is measured based on the ratio of the wet surface area (Ab) to the area of its projection plane (Ap), or Hr = Ab / Ap. Samples were taken randomly on the System IV channel of Denpasar City, with a total of 30 samples. From many samples, the smallest hr value (hrmin), the largest (hrmax), and the Range (R = hrmax-hrmin) were sought. Next, a combination of the hr measurement results with the criteria (good, moderate, and poor) and their relationship with the no. The results obtained from this study are that the stone pair has good criteria if < 1.097 and no = 0.015, moderate/normal 1.097 ≤ hr ≤ 1.152 and no = 0.018, and bad if hr > 1.152 and no = 0.030.

Keywords: Hydraulic roughness; Manning coefficient; value criteria;

1. INTRODUCTION

The reliability of drainage channels in accommodating flooding is none other than their capacity. Open capacity is determined by flow velocity (V), which is influenced by flow resistance. Flow resistance in open channels occurs due to the frictional force between the flowing fluid and the hydraulic surface of the channel cross-section. Based on the general theory of friction, the relationship between flow resistance and hydraulic roughness is proportional: the rougher the hydraulic surface, the greater the frictional force between the fluid and the channel surface, and vice versa. Consequently, the greater the resistance to flow velocity (Li et al., 2016). The effect of hydraulic roughness on flow velocity in open channels is expressed by the hydraulic roughness coefficient. The hydraulic roughness coefficient most widely used to analyze the capacity of open channel cross-sections is the Manning roughness coefficient (n.u.). The Manning roughness coefficient (n.u.) has been taken from several references, such as Zane, Chow, and the Department of Public Works, Directorate General of Highways, Directorate of City Road Development (for roadside channels). These references determine the Manning roughness coefficient (no) subjectively, namely, based on the type of material. For example, stone masonry material is considered to have lower hydraulic quality than concrete material, so the value of the roughness coefficient (no) of stone masonry is greater than the hydraulic roughness coefficient (no) of concrete material. In addition, the same material is also categorized based on the quality of workmanship; the better the quality of workmanship, the smaller the value (no), and vice versa. Zane (2010) relates the type of material and work quality with the Manning roughness coefficient (no) based on the minimum and maximum value categories, Chow (1959) relates the type of material and work quality with the Manning coefficient (no) based on the minimum, normal and maximum value categories, and the Department of Public Works, Directorate General of Highways, Directorate of City Road Development (1990) relates the type of material and work quality with the Manning coefficient (no) based on the value categories of excellent, good, moderate, and poor.

There is no objective standard that can be used to select one of the qualities of work or material from the existing categories, so the determination of the Manning roughness coefficient value (no) from the reference is very subjective. The quality of work/material with the categories of minimum, maximum, excellent, good/moderate, and poor does not have objective limits. However, determining and/or testing the quality of a job is one of the most important things in construction work (Sutapa et al., 2022). Almost all the quality/quality of construction work materials can be determined objectively, for example, concrete quality is determined by the characteristic compressive strength value (f'c), steel quality is determined by the tensile strength number (fy), the quality of highway surfaces is determined by the International Road Index (IRI) or Road Condition Index (RCI), but the hydraulic quality of drainage channel surfaces is still determined subjectively, namely based on the values: excellent, good, moderate/normal and poor, related to the Manning roughness coefficient number of the channel material (no).

Suparta (2018) quantified the hydraulic roughness (hr) of masonry with broadcasts based on the ratio between the wet surface area (AB) and its projected area (AP), or hr = AB/AP. The wet surface area (AB) is the surface area calculated based on the length of the wet path, measured using a wet thread (attached to the entire surface area). Meanwhile, the projected area (AP) is calculated based on the area of the flat plane. The hr value can be combined with the subjective quality contained in the references used to determine the Manning roughness coefficient (no) such as: very good, good, medium/normal, poor, minimum and maximum categories, related to the Manning roughness coefficient (no), so that it becomes a standard measure of material quality and objective (measurable) work quality.

This study aims to create a combination of subjective quality values of materials/works in the references (Zane, 2010; Chow, 1959; SNI 2830, 2008; DPU RI, 1990) and relate them to the Manning roughness coefficient (no) in each of these references. The results of this study are in the form of a combination of hydraulic roughness (hr) with subjective values of subjective hydraulic quality (very good, good, moderate/normal, poor, minimum and maximum) and their relationship with the Manning roughness coefficient (no). So that a method is obtained to determine and measure/test the quality of materials and open channel construction work that is easy, simple, and measurable.

Literature review

To measure road surface quality, AASHTO recommends the NAASRA method (SNI 03-3426-1994), with the roughness measure being the International Roughness Index (IRI). The IRI is a roughness parameter calculated based on the cumulative number of ups and downs of the road surface along the longitudinal profile divided by the distance/length of the measured surface (Sugiharto, 2004). Besides the IRI, road surface quality can also be determined based on the Road Condition Index (RCI) value, obtained using a roughometer or manually using a simple tool (tape measure) combined with visual observation. The roughometer yields the International Roughness Index (IRI) value, which is then converted to obtain the RCI value (Anisarida, 2017).

measures the configuration of surface irregularities of an object/material using a reference profile. The reference profile used is the center profile or base profile. The center profile is a profile that is shifted to the middle between the highest and lowest points of the profile. The roughness measure is the surface area above the reference divided by the area of the reference plane. The base profile is a reference profile that is shifted down so that it touches the lowest point of the measured profile. The roughness measure is the surface area above the reference divided by the area of the reference plane. This method is widely used to measure the quality of steel cutting work results (Attari et al., 2021).

A method similar to the IRI/RCI method was carried out by Idiot (2012), who measured the surface roughness of a material/object based on the number of up and down movements, or based on the height of the incline (peak) and decline (valley). Idiot described the surface roughness of an object into 3 (three), namely: (1) statistical description, using the average value of the surface height, (2) extreme value description, namely based on the condition of the maximum peak value towards the maximum valley value or the difference between the maximum peak value and the maximum valley value, (3) texture description, namely based on the measurement results against the measurement length (traversing length). This method is often used to measure the quality of steel surface work. (Suparta, 2018) modified the Balinese style work volume measurement method by using a wet thread path attached to the work surface that is measured in the length and width directions, and then calculating the area to obtain the wet area. Suparta compared the wet area with its projected area (flat surface area) to obtain the ratio of the wet area to its projected area as follows:

$$hr = \frac{AB}{AP} \tag{1}$$

Which:
hr = hydraulic roughness
AB = wet cross-sectional area
AP = projection area

$$AB = lv \times lh \text{ or } AB = ll \times lt \tag{2}$$

Which:
lv = length of the wet track in the vertical direction.
lh = length of the wet track in the horizontal direction.
ll = length of the wet track in the longitudinal direction.
lt = length of the wet track in the transverse direction.

The wetted surface area (AB) on the wall is calculated based on the product of the horizontal wetted path length (lh) and the vertical wetted path length (lv), and the wetted surface area at the bottom of the channel is calculated based on the product of the longitudinal wetted path length (ll) and the transverse wetted path length (lt). The path lengths (lv, lh, ll, and lt) of the material surface are measured using a wet thread attached to the surface. Meanwhile, the projected area is calculated based on the flat surface area, namely, for the channel wall, it is the result of multiplying the vertical flat length by the horizontal, and for the channel base, it is the result of multiplying the transverse flat length by the longitudinal. The flow velocity formula (V) for uniform flow in an open channel according to Manning

$$V = \frac{1}{n_o} R^{\frac{2}{3}} S^{\frac{1}{2}} \tag{3}$$

With the following information:
V : flow velocity.
no : Manning's roughness coefficient (depending on material and workmanship).
R : hydraulic radius.

Keulegan (1938), states that the Manning roughness coefficient (n) is very suitable for calculating the channel roughness coefficient in channels with large surface roughness (however, there is no explanation of how to determine the value of the surface roughness in question). Manning's formula is very simple and easy to apply, but according to Graf (1998), the Manning formula is only suitable for rough turbulent flow and at high Reynolds numbers. To be able to use the Manning formula for uniform flow, the slope of the energy line is modified to reflect energy loss due to friction (Coon, 1995). According to formula (3), the main parameter that determines the flow velocity is:

1) Nilai koefisien kekasaran Manning (no).

2) Kemiringan egergi (S).

3) Jari-jari girasi ®.

If the S and R parameters are kept the same, then the only factor influencing the flow velocity (V) according to formula (3) is the Manning roughness coefficient (no). The Manning roughness coefficient (no) value for masonry with a broadcast is available in several references, namely:

1) Zane (2010) determines the no value based on two categories: maximum and minimum values, as presented in Table 1.

Table 1
Manning Roughness Coefficient (no) according to Zane

Manning's Roughness Coefficient, *n*.	Manning's *n*	
Type of Pipe	Min.	Max.
Glass, brass, or copper	0.009	0.013
Smooth cement surface	0.010	0.013
Wood-stave	0.010	0.013
Vitrified sewer pipe	0.010	0.017
Cast-Iron	0.011	0.015
Concrete, precast	0.011	0.015
Cement mortar surfaces	0.011	0.015
Common-clay drainage tile	0.011	0.017
Wrought Iron	0.012	0.017
Brick with cement mortar	0.012	0.017
Riveted-steel	0.017	0.020
Cement rubble surfaces	0.017	0.030
Corrugated metal storm drain	0.020	0.024

(Source: Zane, 2010)

2) (Chow, 1959; SNI 2830, 2008) recommends n values based on 3 (three) categories, namely: minimum, normal, and maximum values, as presented in Table 2.

Table 2
Manning's Roughness Coefficient (no) according to Chow (1959)

Type of channel and description	Minimum	Normal	Maximum
1. Sewer with manholes, inlet, etc., straight	0.013	0.015	0.017
2. Unfinished, steel form	0.012	0.013	0.014
3. Unfinished, smooth wood form	0.012	0.014	0.016
4. Unfinished, rough, wood form	0.015	0.017	0.020
a. Wood			
1) Stave	0.010	0.012	0.014
2) Laminated, trested	0.015	0.017	0.020
b. Clay			
1) Common drainage tile	0.011	0.013	0.017
2) Vitrified sewer	0.011	0.014	0.017
3) Vitrified sewer with manholes, inlet, etc.	0.013	0.015	0.017
4) Vitrified subdrain with open joint	0.014	0.016	0.018
c. Brickwork			
1) Glazed	0.011	0.013	0.015
2) Line with cement mortar	0.012	0.015	0.017
d. Sanitary sewer casted with sewage slims, with bends and connections	0.012	0.013	0.016
e. Paved invert, sewer, smooth bottom	0.016	0.019	0.020
f. Rubble masonry, cemented	0.018	0.025	0.030

(Source: Chow, 1959)

3. (Indonesian Department of Public Works, 1990), recommends determining the no value based on 4 (four) categories, namely: excellent, good, fair, and poor quality, as presented in Table 3.

Table 3
Manning's Roughness Coefficient (n) according to the Indonesian Department of Public Works

No	Channel Type	Very good	Good	Average	Poor
	Artificial channels, concrete, or river stone				
16.	Stone masonry channels, unfinished	0.025	0.030	0.033	0.035
17.	Like no. 16 but with finishing	0.017	0.020	0.025	0.030
18.	Concrete channels	0.014	0.016	0.019	0.021
19.	Smooth and level concrete channels	0.010	0.011	0.012	0.013
20.	Precast concrete channels with steel forms	0.013	0.014	0.014	0.015
21.	Precast concrete channels with wooden forms	0.015	0.016	0.016	0.018

(Source: Indonesian Department of Public Works, 1990)

Theoretical Basis

If the hydraulic roughness (hr) of the channel material is quantified using the comparison method between the wetted surface area (AB) and its projected area (AP) as in formula (1), then a correlation can be made between the hr value and the subjective hydraulic quality values: very good, good, moderate/normal, minimum, maximum, and poor, as well as their relationship with the Manning roughness coefficient (no) according to the reference used. The results of this correlation produce a relationship between the subjective hydraulic quality value with hr and the Manning roughness coefficient (no) according to the referenced reference. Thus, the determination of the Manning roughness coefficient (no) value can be done objectively (de FSM Russo & Camanho, 2015).

2 Materials and Methods

This research was conducted on a stone masonry drainage channel finished with a siding, in the System IV drainage channel in Denpasar City. Sampling was carried out randomly on primary, secondary, and tertiary channels. Samples were taken from accessible channels and measured well/accurately. The number of samples taken was 30 in 10 areas. Samples were taken only on the channel walls because some of the channel bottom was submerged by water flow, and some were sedimented, so that measurements could not be carried out properly/accurately. Measurements were carried out using a square measuring plot method with a length and width of 50 cm. The dimensions of the measuring plot were made with a size of 50 cm x 50 cm to anticipate the depth of the tertiary channel, which is generally relatively shallow, at the study location, around 60-70 cm. The samples taken were the length of the wet path in the vertical and horizontal directions. Each sample was measured three (3) times in the vertical direction (lv1, lv2, lv3) and horizontal direction (lh1, lh2, lh3), then averaged and used as a representative of the vertical direction (lv) and horizontal direction (lh) samples, as shown in Figure 3.

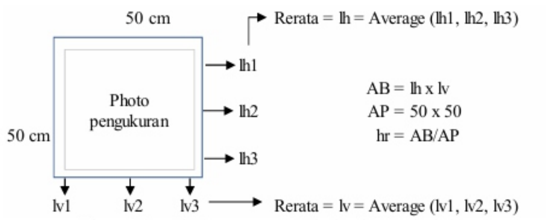

Figure 3. Sample Measurement Method and AB Calculation
(Source: skema metode pengambilan sample, 2022)

From all the data from the lv and lh measurements, the wetted surface area (AB) is calculated using formula (2) and hr using formula (1). Next, the range (R) of the hr value is found, which is the difference between the largest hr value and the smallest hr value (R = hrmax – hrmin). The hydraulic roughness values (hr) from the calculations above are grouped into several groups according to the references used so that they can be combined with the hydraulic quality as follows:

1. (Zane, 2010) groups subjective hydraulic quality values into two groups: minimum and maximum. Therefore, hydraulic roughness (hr) is also divided into two groups by creating a range of hr values from minimum hr + 1/2R and maximum hr - 1/2R. The correlation and its relationship with the Manning roughness coefficient (no.) are presented in Table 4.

Table 4
Correlation Scheme of Subjective Hydraulic Values with Hydraulic Roughness Numbers and Their Relationship with the Manning Roughness Coefficient (Zane, 2010).

No	Katagori	Hydraulic roughness (hr)	n_o
1	Min	hrmin s/d < hrmin+1/2R	0.017
2	Max	hrmin+1/2R ≥ s/d hrmax	0.030

(Source: skema analisis; Zane, 2010)

2. (Zane, 2010) groups subjective hydraulic quality values into two groups: minimum and maximum. Therefore, hydraulic roughness (hr) is also divided into two groups by creating a range of hr values from minimum hr + 1/2R and maximum hr - 1/2R. The correlation and its relationship with the Manning roughness coefficient (no.) are presented in Table 4.

Table 4
Correlation Scheme of Subjective Hydraulic Values with Hydraulic Roughness Numbers and Their Relationship with the Manning Roughness Coefficient (Zane, 2010)

No	Katagori	Hydraulic roughness (hr)	n_o
1	Min	hrmin s/d < hrmin+1/3R	0.015
2	Normal	hrmin+1/3R ≥ s/d hrmin + 2/3R	0.018
3	Max	hrmin + 2/3R > s/d hrmax	0.030

(Source: skema analisis; Chow, 1959)

3. (DPU RI, 1990) groups the subjective values of hydraulic quality into four (4) groups, namely: very good, good, normal, and poor. Therefore, hydraulic roughness (hr) and hr are made into four (4) groups by creating a range of hr values from hrmin to hrmin + 1/4R, hrmin + 1/4R ≥ to < hrmin + 1/2R, hrmin + 3/4R ≥ to < hrmin + 3/4R ≥ hrmax, and the relationship between the Manning roughness coefficient (no.), as presented in Table 6.

Table 6
Scheme for Matching Subjective Hydraulic Values with Hydraulic Roughness Numbers and Their Relationship with the Manning Roughness Coefficient Based on the DPU RI Reference (1990)

No	Katagori	Hydraulic roughness (hr)	n_o
1	Baik sekali	hrmin s/d < hrmin + 1/4R	0.017
2	Baik	hrmin + 1/4R ≥ s/d hrmin + 2/4R	0.020
3	Sedang	hrmin + 2/4R > s/d hrmin + 3/4R	0.025
4	Jelek	hrmin + 3/4R > s/d hrmax	0.030

(Source: skema analisis; DPU RI, 1990)

3 Results and Discussions

The results of horizontal and vertical wet path measurements, as well as hydraulic roughness (hr) values at the study location, show very diverse values, as presented in Table 7.

Table 7
Data on Measurement Results of lv, lh, AB, and hr Calculations in the Denpasar City Drainage System IV Channel

No	lv	lh	AB	AP	hr
1	51.73	51.40	2,659	2,500	1.06364
2	55.70	57.33	3,193	2,500	1.2774
3	52.30	52.83	2,763	2,500	1.1053
4	52.70	53.83	2,837	2,500	1.1348
5	53.00	54.67	2,897	2,500	1.1589
6	52.63	53.00	2,790	2,500	1.1158
7	52.20	51.50	2,688	2,500	1.0753
8	53.20	52.83	2,811	2,500	1.1243
9	53.57	52.07	2,789	2,500	1.1156
10	54.03	52.03	2,812	2,500	1.1246
11	52.80	52.90	2,793	2,500	1.1172
12	53.70	53.60	2,878	2,500	1.1513
13	53.53	52.67	2,819	2,500	1.1278
14	54.47	53.47	2,912	2,500	1.1649
15	53.83	52.83	2,844	2,500	1.1377
16	52.50	52.63	2,763	2,500	1.1053
17	52.40	50.53	2,648	2,500	1.0592
18	53.23	52.67	2,804	2,500	1.1214
19	52.93	52.47	2,777	2,500	1.1109
20	51.97	51.83	2,694	2,500	1.0774
21	54.87	53.53	2,937	2,500	1.1749
22	51.57	52.10	2,687	2,500	1.0746
23	51.80	51.20	2,652	2,500	1.0609
24	51.53	50.57	2,606	2,500	1.0423
25	52.47	52.80	2,770	2,500	1.1081
26	52.00	51.73	2,690	2,500	1.0761
27	51.53	50.57	2,606	2,500	1.0423
28	53.03	52.53	2,786	2,500	1.1144
29	51.97	53.10	2,759	2,500	1.1038
30	53.33	52.40	2,795	2,500	1.1179

From Table 7, it can be seen that the HR value of the rock pairs with broadcasts in the study area varies greatly. The minimum hydraulic roughness value (hrmin = 1.04235), maximum (hrmax = 1.27739), Range (R = HRmax – HRmin = 0.16458), Average = 1.11280. The combination of subjective values of hydraulic quality with hydraulic roughness numbers (hr) and their relationship with the Manning roughness coefficient (no), for each reference, is as follows:

1. Zane (2010)

Because Zane (2010) created two value categories: minimum and maximum, the corresponding matching groups must also be divided into two groups: (1) hrmin to less than hrmin + ½ hr, (2) ≥ hrmin + ½ hr to hrmak, as presented in Table 8.

Table 8
Results of Matching Subjective Hydraulic Quality Values with Hydraulic Roughness (hr) and Manning Roughness Coefficient (no), Using Zane (2010) References

No	Katagori	Hydraulic roughness (hr)	n_o
1	Min	1.04235 sampai < 1.12464	0.017
2	Max	1.12464 ≥ sampai 1.27739	0.030

Source: Analysis Results and Zane (2010).

2. Chow (1959)

Based on Chow's (1959) reference, the subjective hydraulic quality of channel materials is divided into minimum, normal, and maximum values. Therefore, their correlation with hr and (no) can be created, as shown in Table 9.

Table 9
Results of Correlating Subjective Hydraulic Quality Values with Hydraulic Roughness (hr) and Manning's Roughness Coefficient (no), Using Chow's (1959) Reference

No	Katagori	Hydraulic roughness (hr)	n_o
1	Min	1.04235 sampai < 1.09721	0.015
2	Normal	1.09721 ≥ sampai 1.15207	0.018
3	Max	1.15207 > sampai 1.27739	0.030

Source: Analysis Results and Chow (1959)

3. Indonesian Department of Public Works (1990).

According to Road Surface Drainage Design Instructions No. 008/T/BNKT/1990, the n value for masonry with broadcasts is determined based on four categories: Very Good (n = 0.017), Good (n = 0.020), Fair (n = 0.025), and Poor (n = 0.030). Results of Comparing Subjective Hydraulic Quality Values with Hydraulic Roughness (hr) and Manning's Roughness Coefficient (n), Using the DPU RI Reference (1990).

Table 10
Results of Comparing Subjective Hydraulic Quality Values with Hydraulic Roughness (hr) and the Relationship between Manning's Roughness Coefficient (n), Using the DPU RI Reference (1990)

No	Katagori	Hydraulic roughness (hr)	n_o
1	Baik sekali	1.04235 sampai < 1.08349	0.017
2	Baik	1.08349 ≥ sampai 1.12464	0.020
3	Sedang	1.12464 > sampai 1.16578	0.025
4	Jelek	1.20693 > sampai 1.27739	0.030

Source: Analysis Results and DPU RI (1990)

4 Conclusion

From the discussion, it can be concluded that:

a) The calculation of the wet cross-sectional area (AB) of masonry with broadcasts can be performed by measuring the wet path using a wet thread path.

b) The combination of subjective values of hydraulic quality with hydraulic roughness (hr) and its relationship with the Manning roughness coefficient (no) can be used to determine the Manning roughness coefficient (no) of the channel material, with objective, rational, and measurable results.

Conflict of interest statement

The author declared that he has no competing interests

Statement of authorship

The author has a responsibility for the conception and design of the study. The author has approved the final article

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References

Anisarida, A. (2017). Evaluasi Kondisi Permukaan Jalan Dengan Metode Road Condition Index (RCI). GEOPLANART, 1(2), 13-21.

Anon. (2015). Buku Ajar Hidraulika, web.ipb.ac.id, www.google.co.id. Attari, M., Taherian, M., Hosseini, S. M., Niazmand, S. B., Jeiroodi, M., & Mohammadian, A. (2021). A simple and robust method for identifying the distribution functions of Manning's roughness coefficient along a natural river. Journal of Hydrology, 595, 125680. https://doi.org/10.1016/j.jhydrol.2020.125680

Coon, W. F. (1995). Estimates of roughness coefficients for selected natural stream channels with vegetated banks in New York (US Geological Survey Open-File Report 93-161). US Geological Survey. de FSM Russo, R., & Camanho, R. (2015). Criteria in AHP: A systematic review of literature. Procedia computer science, 55, 1123-1132. https://doi.org/10.1016/j.procs.2015.07.081

Departemen Pekerjaan Umum. (1990). Petunujuk Desain Drainase Permukaan Jalan NO. 008/T/BNKT/1990,

Direktorat Jenderal Bina Marga, Direktorat Pembinaan Jalan Kota. Graf, W. H. (1998). Fluvial hydraulics: Flow and transport processes in channels of simple geometry. John Wiley & Sons

Idiot. (2012). Prinsip Kerja Alat Ukur Surface Measurement Roughtness. Keulegan, G. H. (1938). Laws of turbulent flow in open channels. National Bureau of Standards. Li, B., Liu, R., & Jiang, Y. (2016). Influences of hydraulic gradient, surface roughness, intersecting angle, and scale effect on nonlinear flow behavior at single fracture intersections. Journal of Hydrology, 538, 440-453. https://doi.org/10.1016/j.jhydrol.2016.04.053

Purbosari, D. (2012). Karakterisasi tingkat kekasaran permukaan baja st 40 hasil pemesinan CNC milling ZK 7040 efek dari kecepatan pemakanan (feed rate) dan awal waktu pemberian pendingin.

Standar Nasional Indonesia (SNI 2830:2008). (2008). Tata cara perhitungan tinggi muka air sungaidengan cara berdasarkan rumus Manning, ICS 93.010 Badan Standardisasi Nasional.

Sugiharto, A. M. (2004). Tingkat Kerataan Jalan Berdasarkan Alat Rolling Straight Edge Untuk Mengestimasi Kondisi Pelayanan Jalan (PSI dan RCI). Simposium VII FSTPT, Universitas Katolik Parahyangan

Suparta, I. W. (2020). Analisis Hubungan Antara Kekasaran Permukaan Bahan Dasar Saluran Dengan Koefisien Kekasaran Manning Di Dalam Saluran Terbuk

Suparta, I. W., Nadjadji, A. & Umboro, L. (2018). Menentukan Koefisien Kekasaran Manning (n) Pasangan Batu Dengan Finishing (Siaran) Berdasarkan Kuantifikasi kekasaran Hidraulis, Pertemuan

Ilmiah Tahunan HATHI XXXV Medan 2018.

Sutapa, I. K., Yuni, N. K. S. E., Susila, I. N. D., Wibawa, . I. G. S., & Santiana, I. M. A. (2022). Evaluation of the implementation of occupational safety and health management systems on the ayana nort wing bali construction project. International Research Journal of Engineering, IT and Scientific Research, 8(1), 1–6. https://doi.org/10.21744/irjeis.v8n1.2034

Zane Satterfield, P. E. (2010). Fundamentals of Hydraulics: Pressure. Tech Brief, 9(4), 1-4.

Characteristics of "Eco Green Concrete" Concrete with Locagramic Additional Materials

Iwan Supardi a Deny Syahrani b Rasiwan c M. Abduh d Etty Rabihati e Rika Riyanti f

A B S T R A C T

Commonly used concrete is made from a mixture of fine aggregate (sand), coarse aggregate (gravel), cement, and water. These constituent materials come from nature and have been processed and selected according to their needs. As time passes, the widespread use of concrete as a construction material can disrupt the balance of the surrounding environment, given the reduction in the ingredients of concrete available in nature. Therefore, we need an innovation that can be a choice in using concrete without destroying our natural resources, usually called Green Concrete or Eco Green Concrete. In other words, the level in this research is an appropriate technology for replacing building materials. The problem is how much influence the percentage of glass bottle powder, ceramic powder, and granite powder waste has in achieving the slump test value and the planned increase in compressive strength. Know the compressive strength of concrete using added Lokagrmic waste (glass bottle powder, ceramic powder waste, and granite powder waste). The method used is by conducting research in the laboratory, especially the civil engineering laboratory, using a variation of 2.5%, 5% and, 7.5%, 10% loagrik material samples with a treatment time of 3 days, seven days, and 28 days, the next step is to test the compressive strength of concrete and the split tensile strength of the concrete while the concrete made is 20 Mpa.

Keywords: additional materials; granite powder waste; green concrete karstic; innovation; lokagramik waste;

1. INTRODUCTION

The progress of the current global era cannot be separated from developments in the construction sector, which are increasingly creative and innovative. One of them is using concrete as part of building construction. It is relatively strong, can be shaped according to needs, and is more economical than other construction materials that use steel or wood.

Commonly used concrete is made from a mixture of fine aggregate (sand), coarse aggregate (gravel), cement, and water. These ingredients come from nature and have been processed and selected according to their needs. As time goes by, the widespread use of concrete materials for construction can disrupt the balance of the surrounding environment, considering the reduction in the materials that make up concrete available in nature. Therefore, we need an innovation that can be a choice for using concrete without destroying our natural resources, usually called Green Concrete or Eco Green Concrete (Kirthika & Singh, 2020; Suhendro, 2014; Habert et al., 2010).

One alternative that can be done without reducing the strength of the concrete itself is to use additional materials derived from building materials, which can be reprocessed according to needs and minimize the use of cement. For this reason, additional materials are needed, such as glass bottle waste, ceramics, and granite, as a substitute for cement.

Minimizing the use of cement and replacing it by adding some waste which is intended as additional material, raises problems that question how significant the influence of the percentage of glass bottle powder waste, ceramic powder waste, and granite powder waste is in the role of achieving the slump test value and the planned increase in compressive strength (Saputra, 2019; Aıtcin, 2003; Hoseini et al., 2009; Santri et al., 2021

2 Materials and Methods

This research will be carried out for six months. Testing was carried out at the Pontianak State Polytechnic Civil Engineering Laboratory. Research methods are structured in such a way as to make it easier to research so that it runs more effectively and efficiently. The stages of the implementation procedure are depicted in a flow diagram below:

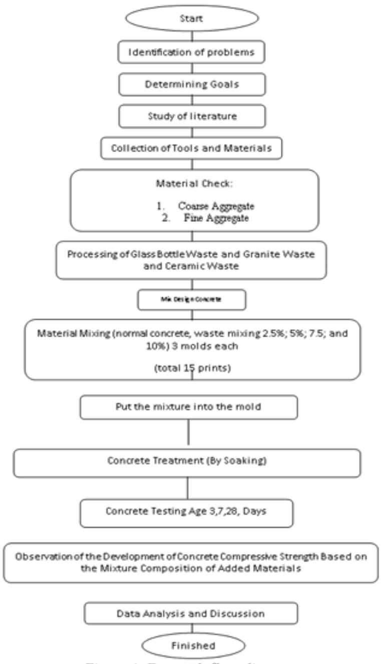

Figure 1. Research flow diagram

Research implementation stage

There are several steps in carrying out this research according to the flow diagram above (figure 1):

1) Prepare tools and materials

2) Carry out aggregate testing

3) Processing glass bottle waste, granite waste, and ceramic waste

4) Create a concrete job mix design

5) Make a test object in the form of a concrete slender measuring 15 cm in diameter and 30 cm high with several

variations of grammatically added materials 0 %, 2.5%, 5%, 7.5 %, 10 %

6) Carry out concrete maintenance for three days, seven days, and 28 days

7) Carry out concrete compressive strength and concrete split tensile strength tests

Table 1
Aggregate testing procedures

NO	Examination	Standard Examination	Unit
A	Coarse Aggregate		
1	Graduation	SNI 03-1968-1990	%
2	Abrasion	SNI 03-2417-1991	%
3	Specific Gravity	SNI 03-1969-1990	
4	Moisture Content	SNI 03-1971-1990	
5	Bulk Density	SNI-03-4804-1998	
B	Fine Aggregate		
1	Graduation	SNI 03-1968-1990	%
2	Specific Gravity	SNI 03-1970-1990	
3	Moisture Content	SNI 03-1971-1990	
4	Bulk Density	SNI-03-4804-1998	

Mixed design calculations (Mix Design)

Mixed Design with a strength of 20 Mpa

Make test objects with a variety of mixtures

1) Normal concrete without added materials;

2) Normal concrete with added material composition of 2.5%, 5%, and 7.5%, 10% (glass bottle waste, granite waste, and ceramic waste).

For each variation, 3 test objects were made, each with a treatment period of 3 days, 7 days, and 28 days

3 Results and Discussions

The results of the OK aggregate testing can be seen in Table 2 below:.

Table 2
Fine aggregate testing

No	Testing	In the market
1	Water content (%)	0,357
2	BJ and Absorption	
	BJ Bulk	2,5079
	BJ SSD	2,5270
	BJ Apparent	2,5567
	Absorption	0,7600
3	Netto	1,6207
4	Mood content (%)	1,12

Table 3
Coarse aggregate testing

No	testing	In Market
1	Water content (%)	0,5207
2	BJ and Absorption	
	BJ Bulk	2,6638
	BJ SSD	2,6817

	BJ Apparent	2,7123
	Absorption	0,667
3	Content Weight	1,4586
4	Abrasion (%)	14,06

Compressive strength

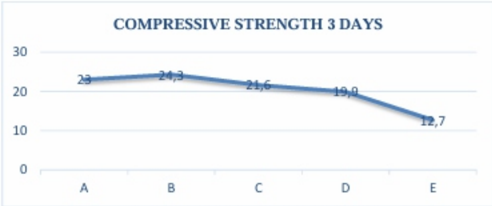

Figure 2. Average compressive strength for each variation

From the picture above, it turns out that the highest compressive strength results are found in variation B, where variation B is with 2.5% added material, which is 24.3 MPa, which is greater than the planned compressive strength, namely 20 MPa, while the lowest variation is in Variation E, which is 12. .7 %

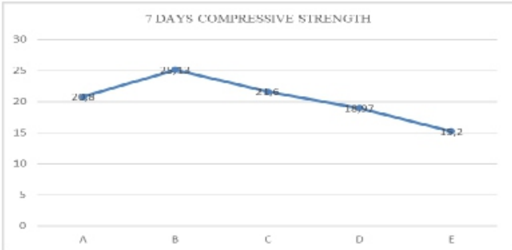

Figure 3. Graph of compressive strength test results at seven days

From the picture above, it turns out that the highest compressive strength results are found in variation B, where variation B is with 2.5% added material, which is 25.13 MPa, which is greater than the planned compressive strength, namely 20 MPa, while the lowest variation is in variation E, which is 19.2. %

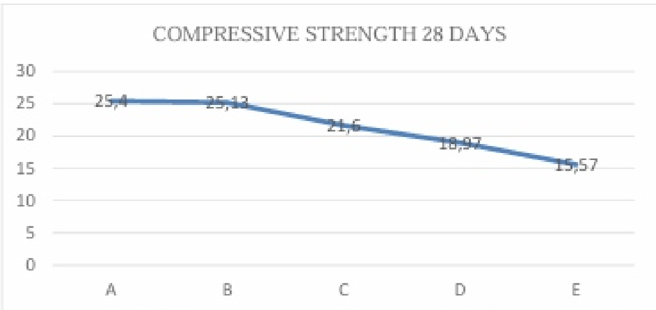

Figure 4. Graph of compressive strength test results at the age of 28 days

From the picture above, it turns out that the highest compressive strength results are found in variation B, where variation B is with 2.5% added material, which is 25.13 MPa, which is greater than the planned compressive strength, namely 20 MPa, while the lowest variation is in Variation E, which is 15.57. Mpa. From the results of observations with different compositions, it was found that the average decrease occurred when using additional waste, and the maximum that occurred when adding waste material was 2.5%, while the minimum compressive strength that occurred when adding 10% of waste was (Batayneh et al., 2007; Meyer, 2009; Army et al., 2022).

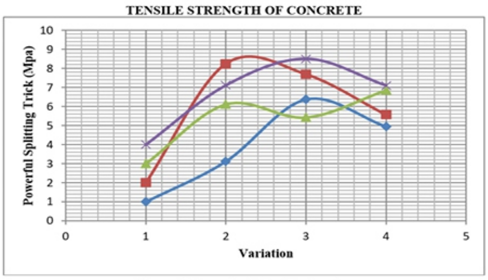

Figure 5. Concrete split tensile strength

From Figure 5, you can see the relationship between the variation, which shows the splitting tensile strength and the age of the concrete. The picture above shows that the maximum splitting tensile strength is 8.2336 MPa for variation 2 for three days of age, while the minimum compressive strength is found in variation 1 for age. Three days with a compressive strength of 3,118 Mpa

Lokagramik concrete as "Eco Green Concrete" concrete
The results of making concrete using local grammatical waste showed that glass, granite, and ceramic waste can be used as additional materials for environmentally friendly concrete, provided they are used in concrete with lowstrength concrete characteristics (Oikonomou, 2005; Donza et al., 2002; Kirthika et al., 2020).

4 Conclusion

From the results of this research, it was concluded that:
a) The variation of adding Lokagramik waste that produces the most significant strength is the variation with the addition of 2.5% waste, which is the maximum for seven days of concrete with a concrete compressive strength of 25.13 Mpa, while the maximum split tensile strength is 8.4125 at three days. Mpa
b) The slightest variation in the addition of Lokagramik waste is the waste variation of 12.5% in 28 days with a concrete compressive strength of 12.7 Mpa, while the minimum split tensile strength is 4.9815 Mpa.
c) The more Lokagramic Waste is added, the smaller the power.

Environmentally Friendly Concrete using Lokagramik Waste can be used but cannot be used for low-strength.

Conflict of interest statement
The authors declared that they have no competing interests.

Statement of authorship
The authors have a responsibility for the conception and design of the study. The authors have approved the final article

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References

Aıtcin, P. C. (2003). The durability characteristics of high performance concrete: a review. Cement and concrete composites, 25(4-5), 409-420. https://doi.org/10.1016/S0958-9465(02)00081-1
Army, B., Sujahtra, I. W., Ramia, I. N., & Sutapa, I. K. (2022). Review of The Use of Cross Iron in Reinforced Concrete Column as An Alternative to Shoes Column. International research journal of

engineering, IT & scientific research, 8(5), 178-186.
Batayneh, M., Marie, I., & Asi, I. (2007). Use of selected waste materials in concrete mixes. Waste management, 27(12), 1870-1876. https://doi.org/10.1016/j.wasman.2006.07.026
Donza, H., Cabrera, O., & Irassar, E. F. (2002). High-strength concrete with different fine aggregate. Cement and Concrete research, 32(11), 1755-1761. https://doi.org/10.1016/S0008-8846(02)00860-8
Habert, G., Bouzidi, Y., Chen, C., & Jullien, A. (2010). Development of a depletion indicator for natural resources used in concrete. Resources, conservation and recycling, 54(6), 364-376. https://doi.org/10.1016/j.resconrec.2009.09.002
Hoseini, M., Bindiganavile, V., & Banthia, N. (2009). The effect of mechanical stress on permeability of concrete: A review. Cement and Concrete Composites, 31(4), 213-220. https://doi.org/10.1016/j.cemconcomp.2009.02.003
Kirthika, S. K., & Singh, S. K. (2020). Durability studies on recycled fine aggregate concrete. Construction and Building Materials, 250, 118850. https://doi.org/10.1016/j.conbuildmat.2020.118850
Kirthika, S. K., Singh, S. K., & Chourasia, A. (2020). Alternative fine aggregates in production of sustainable concrete-A review. Journal of cleaner production, 268, 122089. https://doi.org/10.1016/j.jclepro.2020.122089
Meyer, C. (2009). The greening of the concrete industry. Cement and concrete composites, 31(8), 601-605. https://doi.org/10.1016/j.cemconcomp.2008.12.010
Oikonomou, N. D. (2005). Recycled concrete aggregates. Cement and concrete composites, 27(2), 315-318. https://doi.org/10.1016/j.cemconcomp.2004.02.020
Santri, B., Wahab, Z., Widiyanti, M., & Shihab, M. S. (2021). Effect of image and brand trust on loyalty of cement baturaja consumers. International Research Journal of Management, IT and Social Sciences, 8(2), 141-147.
Saputra, D. (2019). Analisis Kuat Tekan Beton Menggunakan Bahan Tambah Limbah Pecahan Keramik Sebagai Pengganti Sebagian Agregat Kasar (Doctoral dissertation, Universitas Internasional Batam)Suhendro, B. (2014). Toward green concrete for better sustainable environment. Procedia Engineering, 95, 305-320. https://doi.org/10.1016/j.proeng.2014.12.190

Monitoring System for a Self-Consumption Photovoltaic System

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ABSTRACT

Climatic conditions and temperature levels often affect the infrastructure of photovoltaic systems, causing the scheduled generation to not be as expected. The objective was to design a monitoring system for an experimental 3.4 kWp photovoltaic plant that is located on the terrace of building 1 of the Faculty of Engineering and Applied Sciences of the Technical University of Manabí. An automation process was developed to optimize the performance of the installation, using an innovative perspective, the study determinedly faces the initial challenges associated with the software previously used for the design of a data storage system when incorporated into the institutional geoportal. The successful implementation of the Oxley Solar mobile application and, consequently, of the PZM-0043 module, emerges as a comprehensive solution that ensures the continuity of monitoring and contributes significantly to improving the efficiency of the photovoltaic system. The Oxley Solar app overcomes previous limitations by enabling efficient data extraction via Bluetooth and subsequent transmission via WiFi, facilitating more effective storage. The result was the introduction of the PZM-0043 module that adds a layer of automation to the system, guaranteeing continuous data transmission to the database to be stored in the geoportal.

Keywords: automation; data transmission; monitoring system; photovoltaic systems; solar energy;

1. INTRODUCTION

Automation in obtaining information from a photovoltaic plant can involve various technologies and approaches. The automation of the control of photovoltaic plants through automated systems is an area of growing interest, with applications ranging from the protection of solar energy systems to advanced solar tracking programming using specialized software (Caballero, 2019). There are remote monitoring platforms that allow the acquisition, processing and visualization in real-time of detailed information on the operation and performance of isolated photovoltaic systems. These platforms enable continuous monitoring, data analysis and early detection of failures in solar installations (Guamán et al., 2017). The integration of these automation and remote monitoring technologies makes it possible to optimize the operation and maintenance of photovoltaic plants of any scale.

The 3.4 kWp photovoltaic system located on the terrace of building 1 of the Faculty of Engineering and Applied Sciences (FICA), suffered a prolonged period of inactivity due to the mistaken belief that serious and irreparable damage had occurred to the inverter. , an essential component that is responsible for transforming the direct current generated by the photovoltaic panels into alternating current usable by electrical loads. However, a technical inspection revealed that there was no damage to the inverter, but rather a meter connected to its output had failed. By removing this damaged element and connecting the photovoltaic system directly to the building's air conditioning system, the inverter resumed its normal operation (Mahian et al., 2013; Kenisarin & Mahkamov, 2007).

During this reactivation process, the possibility arose of implementing a monitoring system that would allow extracting and recording information in real-time about the electrical generation of the photovoltaic system through the inverter. We worked on an innovative low-cost solution to reactivate and monitor the performance of the photovoltaic system taking advantage of the existing infrastructure (Kannan & Vakeesan, 2016).

Through an exhaustive investigation of the system components, detailed information on the inverter was collected, which led to a thorough analysis of its characteristics, communication and assembly. These specifications were largely documented in the user manual provided by the manufacturer, providing a solid foundation to fully understand the operation of the inverter and its capabilities. Although the manual recommended the use of the Sunny Explorer software (SMA, 2023) to extract data, this solution was identified as not efficient due to the limitation of the connection via Bluetooth, and the lack of data storage if no device was connected.

Faced with the challenge of the range of the connection, innovation was promoted, the search focused on a mobile application that worked similarly to the Sunny Explorer, allowing the extraction of information through Bluetooth and its subsequent sending through Wi-Fi. The main objective was to send and view this information in real-time in the UTM GeoPortal (geoportal.utm.edu.ec, 2018) (Gungor & Lambert, 2006). After extensive analysis, the most suitable option was identified as the Oxley Solar mobile application.

A system was launched that, through the use of the PZM-0043 module, allowed the information to be extracted and sent to the geoportal database. This solution not only overcomes the initial connection limitation but establishes an efficient and continuous solution for PV system monitoring and data storage. The integration of this technology strengthens the monitoring capacity, accessing precise, real-time monitoring of power generation and overall system performance. This advance represents a significant step towards efficiency and automation in the monitoring of photovoltaic installations (Oesterreich & Teuteberg, 2016)

2 Materials and Methods

terrace of FICA building 1, emphasizing the crucial role of automation in obtaining information. To carry out this task, initial inspection and diagnosis were used, performing a detailed visual inspection of all components of the photovoltaic system, visually identifying possible problems, wear or apparent damage, and focusing on the apparent problem of the inverter.

3 Results and Discussions

To achieve the desired results, the resolution of the problems was proposed, the damaged meter that affected the inverter was removed and the photovoltaic system was connected to the building's air conditioning system to restore the proper functioning of the inverter. A meticulous investigation of the system components was carried out, with a primary focus on the inverter, detailed data was collected on the inverter features, communication and mounting. Image 1 shows the characteristics table of the university investor.

Figure 1. Inverter Characteristics Table

Using the nameplate, it was possible to determine that the inverter model is Sunny Boy, which "transforms the direct current of the photovoltaic generator into alternating current and injects it into the public electrical grid" (SUNNY BOY 2500/3000 solar inverter Installation instructions, page 7) and the user manual for this inverter model was easily located.

Revision of the user manual

During this stage, the manual provided by the manufacturer was carefully reviewed, to obtain precise and detailed technical information about the inverter. This allowed essential data to be collected, including maximum input currents and voltages, maximum input power and consumption requirements for optimal operation. Likewise, details were extracted about general aspects and accessories associated with the investor. With this information, the type of communication of the inverter with other devices to obtain data related to the generation of the photovoltaic system was determined (Veliz et al., 2021)

The free software supplied by the company SMA, responsible for the manufacture of the system inverter, was used. The tool used was Sunny Explorer Version 2.01.21.R (www.sma.de, 2020), this software allowed the connection of the inverter with another device using Bluetooth technology. The software interface connected to the inverter, which shows the generation recorded on 02/16/2023, is illustrated in Figure 2, this process is decisive for obtaining and displaying key data related to the generation of the photovoltaic system..

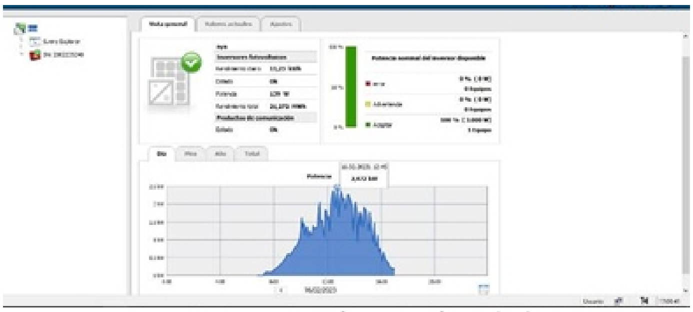
Figure 2. Generation information for 02/16/2023

Sunny explorer software evaluation

Figure 2 presents a graph and a detailed table that reflect the photovoltaic generation of the system in question for 02/16/2023; However, when trying to access the information corresponding to previous days, a significant limitation was evident in the Sunny Explorer software. This system did not store information for days in which no device was connected to the inverter, resulting in a lack of data for those periods. The inefficiency of this methodology was aggravated by the existence of days during which data was not recorded due to the absence of connections.

Innovation and search for alternatives

Given the limitations identified in the Sunny Explorer software, particularly the inability to store data in the absence of connected devices, a strategic decision was made to improve the efficiency of monitoring data generation more consistently. To overcome these limitations and move towards a more robust monitoring system, a search for alternatives was undertaken in the form of more advanced and versatile software. The strategy consisted of identifying solutions that could effectively replace Sunny Explorer, allowing efficient data extraction (Massie et al., 2004; Hameed et al., 2009).

The long-term objective of this initiative was to implement an automated system that not only overcomes the observed limitations but also guarantees continuous and uninterrupted monitoring of the photovoltaic system generation. The active search for more advanced and suitable software was considered decisive to ensure an effective transition towards an optimized monitoring system in line with the most recent standards in photovoltaic technology (Salas, et al., 2006). In the search carried out, we found the Oxley Solar (solar, 2023) mobile application.

The selection of the Oxley Solar Mobile Application and implementation allowed for an innovative system for obtaining data, after an exhaustive analysis, it was chosen as the optimal solution due to its ability to extract data via Bluetooth and transmit it via Wi-Fi. This versatile Android app stands out by supporting Bluetooth connections to SMA Sunny Boy inverters and Wi-Fi connections to the pvoutput.org system (Oxley Web Services, 2023), making it an ideal choice for various setups and use cases, also effectively addresses previous limitations, providing a comprehensive and adaptable solution for photovoltaic system monitoring (Reisi et al., 2013; Sharma & Chandel, 2013).

A phone specifically configured with the Oxley Solar app was initially installed at the inverter location. The uniqueness of this device lies in its constant connection to the inverter, ensuring that the information generated is captured without interruptions. Notably, this phone does not require a battery, allowing it to be continuously connected to a power outlet using an adapter, thus avoiding possible failures due to lack of power. In Figure 3 you can see in (A) the graph of the generation presented and in (B) the image of the phone that is connected to the inverte

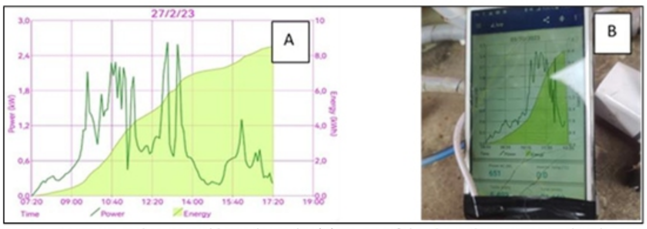

Figure 3. Generation graph presented by Oxley Solar (A), image of the phone that is connected to the inverter

As seen, a clear visual representation of how Oxley Solar presents generation data is offered, highlighting its similarity to the interface of the previously used software, Sunny Explorer. This visual consistency not only makes transitioning between platforms easier but also cements the Oxley Solar app as an ideal alternative. Because the software sends information via Wi-Fi, in collaboration with the FECA, the installation of a Wi-Fi access point was achieved on the terrace, home of the photovoltaic system, to provide connectivity to the connected phone, thus allowing efficient transfer of data to specific destinations. Figure 4 (A) shows the connection of the inverter with the phone and the router, while (B) shows the installation of the Wi-Fi point.

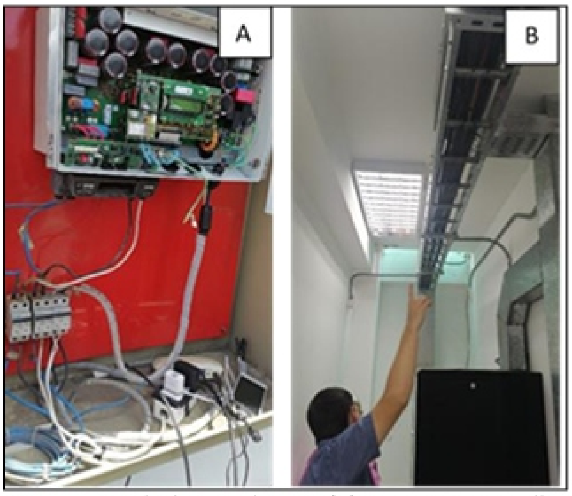

Figure 4. Inverter with phone and router (A), Wi-Fi point installation (B)

he temporary solution of keeping the phone constantly connected represented a short-term measure; however, it was recognized that it was not the optimal long-term option.

Implementation of the data extraction system with Module PZM-0043

The choice of this module was based on the need to overcome previous limitations. The PZEM-004T module is a multifunction meter that allows measuring voltage, current, active power and energy in devices connected to a 110/220V single-phase line. With communication capabilities UART, this module is versatile, being able to send data to microcontrollers, PC, WiFi modules or PLC. (Ssdielect, 2022).

The PZM-0043 module connects to the inverter to obtain the data and send it directly to an ESP8266 WiFi module. The ESP8266 WiFi module is a wireless communication device based on the Tensilica Xtensa L106 Through the ESP8266 module, the data collected by the PZM-0043 module is sent to the database. This approach not only overcomes previous limitations but also establishes a system for continuous monitoring and data storage of the PV system

Establishing an effective connection between the modules and the inverter is crucial to ensure correct data transmission in the system. Figure 5 clearly illustrates the layout and connection of the modules to the inverter, highlighting the importance of this configuration for the efficient sending of information. This strategic step ensures fluid communication between components, facilitating the exchange of essential data for effective monitoring and control of the photovoltaic system.

Figure 5. Connection of the modules to the inverter for data sending

The process of implementation and improvement of the photovoltaic system at the Technical University of Manabí has yielded significant results, marking considerable progress in terms of monitoring and energy efficiency. Below is a detailed analysis of the results obtained:

Inspection of the initial problem in the inverter revealed that the problem resided in a meter connected to the inverter. By removing this component and connecting the photovoltaic system to the building's air conditioning system, it was possible to efficiently reactivate the system, highlighting the importance of an accurate diagnosis.

Initial use of the Sunny Explorer software demonstrated limitations, especially the lack of data storage when no devices were connected. The search for innovative solutions led to the choice of the Oxley Solar mobile app, which offered an efficient way to extract information using Bluetooth and send it over Wi-Fi. This transition resulted in a more dynamic and adaptable system

The inconvenience of constantly keeping a mobile phone connected was overcome by implementing a PZM-0043 module ich allows overcoming connection restrictions and guaranteeing continuous monitoring. This multifunction device, with UART communication capabilities, allowed efficient data extraction and subsequent sending via a PZM-0043 module to the database. This integration represented a significant step forward towards automation and improvement of the monitoring system.

The introduction of modern information and communication technologies has been essential to enhance efficiency in data capture and its intelligent use. Not only does it provide direct and up-to-date access to valuable information, but it also consolidates solid data management that can be essential for analyzing the performance of the photovoltaic system and implementing specific optimization strategies.

The innovative automation system implemented has transformed the photovoltaic plant into a more agile and adaptable installation, with the capacity to respond efficiently to variations in energy demand. This visionary approach, in addition to successfully overcoming initial technical challenges, sets a valuable precedent to drive continuous improvements and disruptive innovations in photovoltaic technology.

The experience and knowledge acquired in this pioneering project stand as an exemplary guide, easily extrapolated to other generation plants, thus contributing to the incessant advancement of photovoltaic technology and its integration into more intelligent, efficient and sustainable electrical networks. This progress is not only an achievement for the specific facility but also illuminates the path toward a cleaner, more self-sufficient energy future.

4 Conclusion

The automation system of the 3.4 kWp photovoltaic plants was implemented, this is positioned as a necessary element to increase the efficiency, performance and reliability of the renewable energy generation installation. Automatic extraction and registration of operational data was achieved, allowing its integration both with the geographic information system and with the SCADA supervision and control platform.

Conflict of interest statement

The authors declared that they have no competing interests

Statement of authorship

The authors have a responsibility for the conception and design of the study. The author(s) have approved the final article.

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References

Caballero, V., Valbuena, S., Vernet, D., & Zaballos, A. (2019). Ontology-defined middleware for internet of things architectures. Sensors, 19(5), 1163.

Guamán, J., Guevara, D., Vargas, C., Ríos, A., & Nogales, R. (2017). Solar manager: Acquisition, treatment and isolated photovoltaic system information visualization cloud platform. POWER, 42(170mA), 700Ma.

Gungor, V. C., & Lambert, F. C. (2006). A survey on communication networks for electric system automation. Computer Networks, 50(7), 877-897. https://doi.org/10.1016/j.comnet.2006.01.005

Hameed, Z., Hong, Y. S., Cho, Y. M., Ahn, S. H., & Song, C. K. (2009). Condition monitoring and fault detection of wind turbines and related algorithms: A review. Renewable and Sustainable energy reviews, *13(1), 1-39. https://doi.org/10.1016/j.rser.2007.05.008*

Kannan, N., & Vakeesan, D. (2016). Solar energy for future world:-A review. Renewable and sustainable energy reviews, 62, 1092-1105. https://doi.org/10.1016/j.rser.2016.05.022

Kenisarin, M., & Mahkamov, K. (2007). Solar energy storage using phase change materials. Renewable and sustainable energy reviews, 11(9), 1913-1965. https://doi.org/10.1016/j.rser.2006.05.00

Mahian, O., Kianifar, A., Kalogirou, S. A., Pop, I., & Wongwises, S. (2013). A review of the applications of nanofluids in solar energy. International Journal of Heat and Mass Transfer, 57(2), 582-594. https://doi.org/10.1016/j.ijheatmasstransfer.2012.10.037

Massie, M. L., Chun, B. N., & Culler, D. E. (2004). The ganglia distributed monitoring system: design, implementation, and experience. Parallel Computing, 30(7), 817-840. https://doi.org/10.1016/j.parco.2004.04.001

Oesterreich, T. D., & Teuteberg, F. (2016). Understanding the implications of digitisation and automation in the context of Industry 4.0: A triangulation approach and elements of a research agenda for the construction industry. Computers in industry, 83, 121-139. https://doi.org/10.1016/j.compind.2016.09.006

Reisi, A. R., Moradi, M. H., & Jamasb, S. (2013). Classification and comparison of maximum power point tracking techniques for photovoltaic system: A review. Renewable and sustainable energy reviews, 19, 433-443. https://doi.org/10.1016/j.rser.2012.11.052

Salas, V., Olías, E., Barrado, A., & Lazaro, A. (2006). Review of the maximum power point tracking algorithms for stand-alone systems. Solar energy materials and solar cells, 90(11), 1555-1578. https://doi.org/10.1016/j.solmat.2005.10.023

Sharma, V., & Chandel, S. S. (2013). Performance and degradation analysis for long term reliability of solar photovoltaic A review. Renewable and sustainable energy reviews, 27, 753-767. https://doi.org/10.1016/j.rser.2013.07.046

Veliz, J. K. M., Gualán, J. F. V., Mateo, F. A. L., Veléz, A. A. G., & Gámez, M. R. (2021). Isolated photovoltaic system for house: pre-sizing. International Research Journal of Engineering, IT & Scientific Research, 7(1), 2532. https://doi.org/10.21744/irjeis.v7n1.1225

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