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ANALYSIS OF WASTE MATERIAL COEFFICIENT FOR CONCRETE CASTING WORK USING BIM CUBICOST TAS

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ABSTRACT

One of the construction project activities that has a large volume of work on the upper structure is casting work. In concrete requirement planning, contractors usually multiply the book by 10%. However, in practice, the concrete requirement is still less than planned. Therefore, concrete requirement planning must be calculated accurately. The volume of concrete needs to be multiplied by the waste material coefficient. This research was conducted on the XYZ Project by directly observing to obtain the volume of realized concrete purchased so that the value of the material coefficient that has taken into account waste material will be obtained. BIM Cubicost TAS is used to minimize planning volume calculation errors. The results of this study show that for horizontal casting work, the largest percentage of residual material is 3.133%, and the average percentage of residual material for horizontal casting is 2.192%. Meanwhile, for vertical casting work, the largest percentage of remaining material is 7.219% and the average percentage of remaining vertical casting material is 3.015%. Finally, the waste material coefficient is obtained as 1.022 for horizontal casting and 1.03 for vertical casting. In the AHSP Ministerial Regulation No. 1 of 2022, the coefficient value of materials for casting work using ready-mix concrete is 1.02. This reveals that the coefficient value in AHSP Minister of Public Works and Public Housing Regulation No. 1 of 2022 has not fully calculated the real waste material in the field. The analyzed coefficient values in this study can be used as a reference for the project to determine coefficients in the AHSP and aid in planning concrete volume requirements because it already takes into account the real waste material in the field.

Keywords: Building Information Modeling (BIM); Casting Work; Cubicost TAS; Coefficient; Waste Material.

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1. INTRODUCTION

The main problem with construction projects is Over Budget. One of the causes of over budget is an error in calculating the volume of work. Concrete work is one of the structural works that has volume calculation errors. Quantity Surveyors sometimes only calculate the real volume of concrete structural work based on DED drawings without paying attention to material waste. Waste material in casting work occurs during the casting process, sometimes during casting there is a spill of concrete material which when the casting process is

finished is not used/discarded. This research needs to be carried out so that material waste is taken into account in calculating the volume of casting work so that there is no longer an over-budget on construction projects.

One of the construction project activities that has a large volume of work on the upper structure is the casting work. The planning of concrete needs must be carefully calculated because the material itself is a cost element that has an important role in supporting the success of a project **(**Allo et al,, 2022). If there is a lot of material waste, then the project is not efficient in trying to minimize the material waste that arises, while minimizing material waste will help reduce environmental impacts and prevent contractors from going over budget (Devi, 2021). Over budget in this case is due to the calculation of ready-mixed concrete requirements that are not thorough whereas in the planning of material requirements, waste material must also be taken into account. Waste material is an excessive or unused amount of material, which ultimately does not add value to the work (Heryanto et al, 2020). Construction Waste can be classified into two categories based on its type, namely:

1. *Direct Waste*
   Direct waste is waste material derived from the project because of damage, or lost and cannot be used anymore.
2. *Indirect Waste*
   Indirect waste is the waste material derived from the project because the volume used exceeds the volume planned, it does not cause the waste material physically in the field and it affects the physical cost in the field and hidden costs.

Concrete is the most crucial construction material chosen for every civil engineering project, and in recent years, concrete waste management has become a critical issue faced by various stakeholders in the construction field (Bilqis & Safri, 2023). There are several causes of material waste in casting work, namely hardened concrete due to slow or improper handling, scattered when transported/moved, and concrete sticks to concrete channels (Hakim, et al., 2023). In addition, the cause can be due to bad weather/rain, ordering errors resulting in less concrete material, and worker error (Sandanayake et al, 2020). The value of concrete waste material can be included in the material coefficient in the unit price analysis.

The material coefficient is a number that indicates the amount of material required for each unit quantity of work (PUPR, 2022). For 1 m^3 of casting work, 1 m^3 of concrete is usually required. However, in reality in the field, several factors cause waste materials that need to be calculated. Therefore, the value of the material coefficient in the AHSP must take into account the waste material or waste material coefficient. AHSP is generally used as a guideline for planning project cost budgets. In addition, the coefficient value in AHSP is useful for knowing how much material needs to be used (Hendra, et al., 2022). AHSP itself has been contained in PerMen PUPR No.1 of 2022 which is used as a basis for compiling the calculation of Harga Perkiraan Sendiri (HPS) or owner's estimate (OE). Contractors, in general, make bid prices based on their analysis based on previous experience in completing a construction job. In the AHSP PerMen PUPR No. 1 of 2022, the material coefficient for casting work using ready-mix concrete is 1.02. The value of 1 means that 1 m^3 of casting work requires 1 m^3 of concrete, while 0.02 or 2% is the value of the material loss factor. The material loss factor aims to take into account the material that is scattered during processing and installation.

Casting work on Project XYZ is carried out nearly every week. The calculation of ready-mix concrete requirements in Project XYZ still employs conventional methods, and contractors usually multiply the volume by 10% to account for any wasted or spilled concrete during mixing at the batching plant. However, during the casting work on Project XYZ, instances occurred where the concrete requirement in the field fell short, necessitating the project to order the shortfall in concrete. If such situations occur frequently, it cannot be denied that the project might face an over-budget scenario. These incidents can also arise due to conventional calculations that are not accurate or precise.

Table 1. Example of XYZ Project Casting Volume Calculation

Lantai	Structural Elements	Unit	Casting Plan Volume	Installed Volume
10	Slab Lt. 10	m³	200	238
11	K7A	m³	17.605	25
	K9			
	CW1			
12	CW1	m³	28.505	35
	K7A			
	K4			
	K5 as 2D			
	K5 as 2C			
	K5 as 3D			
	K5 as 3C			
13	Slab Lt. 13 Zone 1	m³	123	129
	Slab Lt. 13 Zone 2	m³	112	116
14	Slab Lt. 14 Zone 1	m³	95	101
	Slab Lt. 14 Zone 2	m³	133	150

Source: XYZ Project

Based on the data obtained from the XYZ project in Table 1, it is known that in the case of horizontal and vertical casting, the most frequent error is underestimating the concrete requirements. This can be caused because the value of waste concrete materials has not been taken into account and also the calculation of concrete requirements is still using conventional methods. These conventional working methods are inefficient, time-consuming, and prone to error which hurts the project (Layyinatusshifah et al, 2023).

In the Minister of Public Works and Public Housing Regulation No. 22/2018 concerning Guidelines for the Construction of State Buildings, namely high-rise buildings with an area above 2,000 m² and above 2 floors, BIM must be used from the planning stage to construction, and can even be used at the operation and maintenance stage.

The best way to deal with waste is to not generate waste at all. However, a construction project may not generate any waste at all, so the best alternative is to minimize the waste (Fachlevi et al, 2023). Therefore, efforts to overcome the miscalculation of material requirements planning in the XYZ project, namely by using Building Information Modeling (BIM). BIM can speed up time, reduce manpower, and save costs compared to conventional methods (Arif et al., 2021). BIM can also approach controlling material waste in Indonesia through material management (Okiwijaya & Arsyadani, 2019). BIM has several levels and one of them is BIM 5D which can minimize quantity calculation errors. In addition, BIM can provide accurate and automated quantification, and assist in significantly reducing variability in cost estimates (Suwarni, et al, 2021).

The coefficient value of materials that have taken waste into account has never been discussed in previous studies. As for some previous research that is a reference for analyzing concrete material waste, including research conducted by Devi, namely to find out the material that has the potential to cause waste and the percentage of losses, it is found that the K-250 concrete material has a residual material of 3% (Devi, 2021). Septianugraha analyzed the estimation of the material waste index as a tool to control and minimize the occurrence of waste, with the result that ready mix concrete material is the largest waste contributor material and poor planning and calculation of needs are the main factors for this material waste (Septianugraha, 2020). Then Sulistio and Waty conducted a study to determine the amount of loss due to ready-mix concrete and its causes, the results showed that the loss generated by the remaining concrete material was 9.06%. The biggest factor causing the loss of ready mix concrete is: lost due to theft, design changes, complex image detailing,

material orders that do not meet specifications, and scattered when transported or moved (Sulistio & Waty, 2021). The research conducted by Safri aims to find out the application of BIM in the calculation of Quantity Take-off (QTO), getting the result that there is a significant difference in QTO value between conventional calculations and calculations using BIM 5D. BIM 5D displays a more accurate QTO value than conventional calculations. This research aims to analyze the value of the coefficient of materials that have taken into account waste materials, with the use of BIM Cubicost TAS as an effort to minimize errors in the calculation of planning volumes.

2. METHODS

The research was conducted at the XYZ project on floors 10-14 and focused on the upper structure casting work, namely column, beam, and slab elements. The XYZ project is located at Jl. Gading Serpong Boulevard Kav. S8, Tangerang City, Banten. This research was observed for 6 weeks, from May 02 to June 13, 2023. The process of casting concrete on beams and floor slabs can begin after the column structure is completed. The next step is to install scaffolding and formwork, place reinforcement for beams and floor slabs, and finally concrete casting (Baskara, 2022). Concrete casting begins with pouring concrete that is still in plastic condition into the mold, which can be done using a bucket (assisted by heavy equipment) or through a pipe (Baskara, 2022). The casting work at the XYZ Project uses the help of concrete pumps and concrete buckets to pour the concrete. A concrete pump is used for horizontal casting, while a concrete bucket is used for vertical casting.

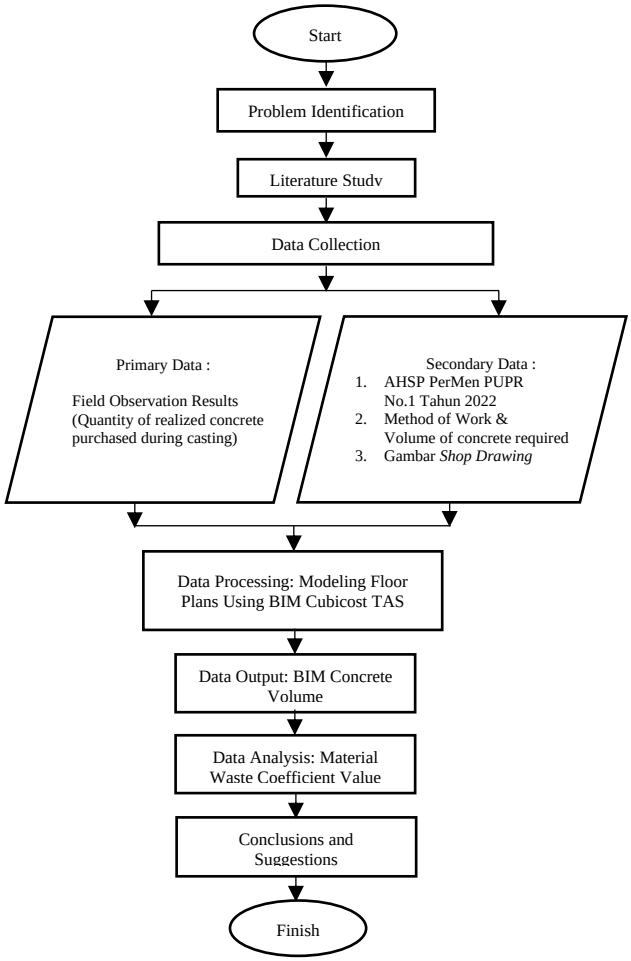

Figure 1. Research Flow Chart
Source: Personal Processed

Based on Figure 1, the data used in this study is primary data obtained through direct observation by recording the number of truck mixers and the quantity of concrete in them. Observations of slabs and beams were made according to the casting zone, while observations of columns and core walls were made according to the schedule in the field. Then for secondary data in the form of AHSP PerMen PUPR No.1 of 2022, casting work methods, shop drawings of upper structure work on floors 10-14. This research data will be processed using BIM 5D-based software assistance, namely Cubicost TAS. This software is specifically designed to assist in the calculation of quantity or take-off quantity and also price. Therefore, for QS Engineers and Estimators, this application can be used to ensure accuracy and precision in their calculations. This software also facilitates Quantity Surveyors to efficiently develop project costs with a 3D model that aligns with measurement standards, and project requirements, and collaboratively manage it with the project team (Fariq et al., 2022). Cubicost TAS provides output in the form of quantity calculations such as area, concrete volume, iron ratio, etc (Baskara, 2022) Another advantage of Cubicost TAS is that it can produce 3D images from 2D images with DWG and PDF file formats, and the results can be exported to PDF and Microsoft Excel (Azmi et al., 2023).

In this research, Cubicost TAS provides the output volume of structural elements for casting planning. After that, it will be analyzed with several stages to get the value of the waste material coefficient. Some of the analysis uses the formula below, namely:

$$Waste\ material\ (X) = Va - Vb - Vc \quad (1)$$

Description:
Vb = Volume of concrete purchased (m^3)
Va = BIM Volume (m^3)
Vc = Used Volume (m^3)

$$Percentage\ waste\ material\ (p) = \frac{X}{Vb}\ x\ 100\% \quad (2)$$

Description:
X = Waste Material (m^3)
Vb = Volume of concrete purchased (m^3)

$$Waste\ material\ coefficient = 1 + p \quad (3)$$

Description:
1 = 1 m^3 of casting work requires 1 m^3 of concrete
P = Percentage of waste material

After processing and analyzing the data, the findings of the material coefficient value that has taken into account the real waste material in the field for casting work will be obtained.

3. RESULTS AND DISCUSSION

3.1 Volume BIM Cubicost TAS

The data processing stage in this research is modeling the structural plan using Cubicost TAS BIM. Modeling is done by importing images still in 2D form, then adjustments are made with existing tools in Cubicost TAS so that the plan can be 3D. BIM volume output results will be obtained in the view quantity by category tool. After that, the concrete volume that has been calculated using Cubicost TAS will be recapitulated according to the structural elements and casting schedule of floors 10-14 in the XYZ project, and the known volume will be multiplied by 10%.

Table 2. Recapitulation of Concrete Volume with BIM Horizontal

Recapitulation of Concrete Volume with BIM Horizontal					
No.	**Floor**	**Date**	**Casting Zone**	**Volume**	**Unit**
1	10	13-Apr-23	Zona 1 (full)	223.072	m³
2	11	10-May-23	Zona 1	126.933	m³
3		13-May-23	Zona 2	114.337	m³
4	12	18-May-23	Zona 1	124.689	m³
5		21-May-23	Zona 2	111.943	m³
6	13	28-May-23	Zona 1	124.689	m³
7		30-May-23	Zona 2	111.943	m³
8	14	05-Jun-23	Zona 2	139.141	m³
9		08-Jun-23	Zona 1	97.158	m³

Source: Personal Processed

Based on Table 2, the BIM volume for the horizontal casting of the 10th floor is 223.072 m³, the 11th-floor zone 1 is 126.933 m³ and zone 2 is 114.337 m³, the 12th-floor zone 1 is 124.689 m³ and zone 2 is 111.943 m³, the 13th-floor zone 1 is 124.689 m³ and zone 2 is 111.943 m³, and the 14th-floor zone 1 is 97.158 m³ and zone 2 is 139.141 m³.

For the vertical casting volume obtained from the BIM results, namely on the 10th floor of 99.198 m³, on the 11th floor of 102.95 m³, on the 12th floor of 102.303 m³, on the 13th floor of 102.307 m³, and the 14th floor of 102.308 m³. The volume mentioned above is the overall volume of vertical casting. The largest casting for the 10th floor on May 2, 2023, was 77.410 m³, for the 11th floor the largest casting was on May 12, 2023, at 52.909 m³, for the 12th floor the largest casting was on May 20, 2023, at 44.406 m³, for the 13th floor the largest casting was on May 31, 2023, at 42.862 m³, and for the 14th floor the largest casting was on June 10, 2023, at 43.541 m³.

3.2 Percentage Waste Material

When the BIM volume and the purchased realization volume are obtained, the waste material in the casting work will be analyzed by reducing the purchased concrete volume by the BIM concrete volume and reducing it by the volume of concrete used outside the planning of casting structural elements.

Table 4. Analysis of Waste Material in Horizontal Casting

Analysis of Waste Material in Horizontal Casting							
No.	**Floor**	**Realistic Concrete Volume (m³)**	**BIM Concrete Volume (m³)**	**Press Test (m³)**	**Returned (m³)**	***Reuse (m³)***	**Waste Material (m³)**
1	10	238	223.0723	1.188	10	-	3.740
2	11	137	126.9334	1.018	3	-	2.049
3		119	114.3373	0.679	2	-	1.984
4	12	130	124.6894	0.679	3	-	2.632
5		117	111.9426	0.679	-	-	2.379
6	13	129	124.6894	0.679	-	-	3.632
7		117	111.9426	0.679	-	-	3.379
8	14	151	139.1412	0848	7	-	3.011
9		102	97.1575	0.679	-	-	3.164

Source: Personal Processed

Based on Table 4, the largest concrete waste material for horizontal casting work on floors 10 through 14 is on floor 10, with a waste material of 3.740 m³.

Table 5. Analysis of Waste Material in Vertical Casting

Analysis of Waste Material in Vertical Casting							
No.	**Floor**	**Realistic Concrete Volume (m³)**	**BIM Concrete Volume (m³)**	**Press Test (m³)**	**Returned (m³)**	***Reuse (m³)***	**Waste Material (m³)**
1	10	81	77.410	1.188	-	1.125	1.277
2		7	6.325	0.170	-	-	0.505
3		17	15.437	0.509	-	-	1.054
4	11	55	52.909	0.848	-	-	1.243
5		25	20.301	0.679	2.5	-	1.121
6		31	29.741	0.679	-	-	0.581
7	12	46	44.406	0.679	-	-	0.916
8		35	32.948	0.848	-	-	1.203
9		27	24.949	0.679	-	0.40	0.972
10	13	48	42.862	0.848	3	-	0.165
11		30	28.574	0.679	-	-	0.748
12		32	30.872	0.509	-	-	0.620
13	14	35	33.549	0.679	-	-	0.773
14		12	11.265	0.339	-	-	0.396
15		15	13.952	0.509	-	-	0.539
16		45	43.541	0.679	-	-	0.780

Source: Personal Processed

According to Table 5, the vertical casting work on floor 10 on May 2, 2023, for 9 columns and 4 core walls, obtained the largest concrete waste material, which is 1.277 m³. The vertical casting work on floor 11 on May 12, 2023, for 6 columns and 3 core walls, obtained the largest concrete waste material, which is 1.243 m³. The vertical casting work on floor 12 on May 22, 2023, for 5 columns and 1 core wall, obtained the largest concrete waste material, which is 1.203 m³. The vertical casting work on floor 13 on June 2, 2023, for 2 columns and 2 core walls, obtained the largest concrete waste material, which is 0.748 m³. The vertical casting on floor 14 on June 10, 2023, for 4 core walls, obtained the largest concrete waste material, which is 0.780 m³.

The value of this waste material has exceeded the deduction from concrete samples for compressive strength tests, concrete returned due to slow handling or suppliers sending materials not according to specifications, and also reused concrete for temporary road projects. So based on data and observations, waste material is the remaining concrete material that cannot be identified physically. In this study, it can be concluded that waste material in the XYZ project for horizontal casting can be caused by some concrete sticking to the joints of concrete pumps or buckets and tremie pipes, scattered concrete due to poorly sealed pipe connections, or exposure to wind during lifting, and also concrete stuck in the concrete pump, and can occur because the batching plant does not deliver concrete according to the quantity ordered. After that, it will be directly analyzed the percentage of waste material, namely using waste concrete material divided by the volume of realized concrete ordered and multiplied by 100%.

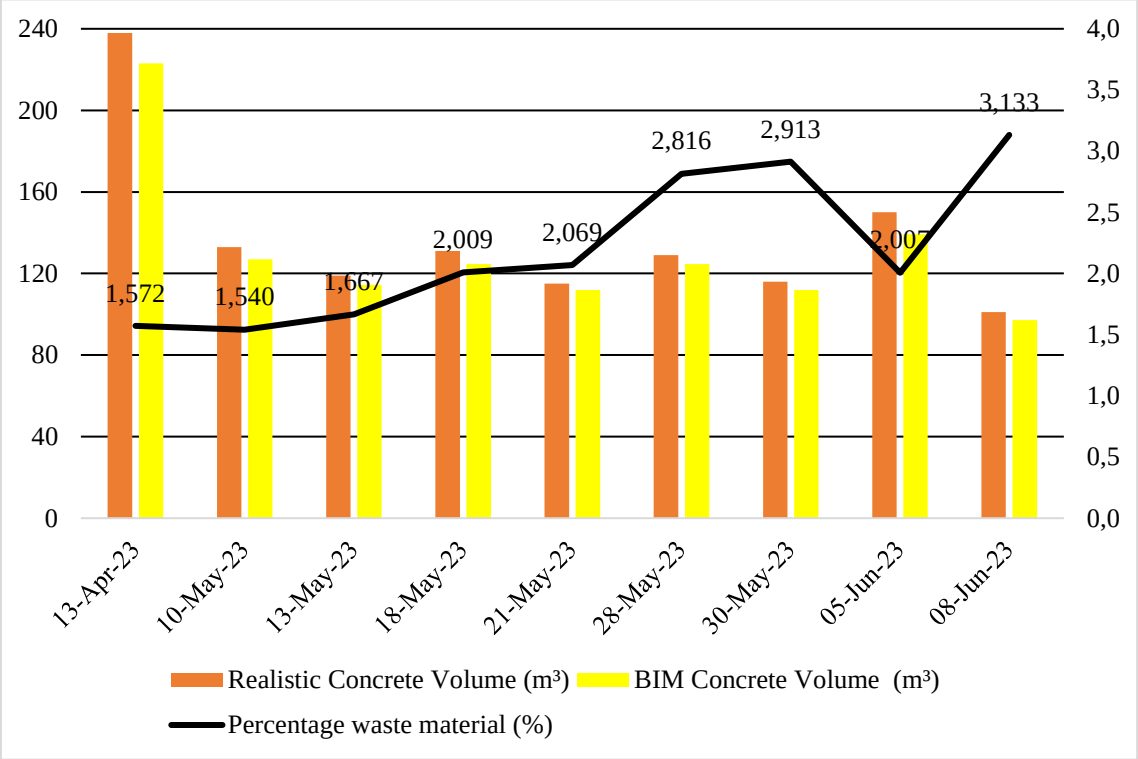

Figure 2. Percentage of *Waste Material* for Horizontal Casting Work

Source: Personal Processed

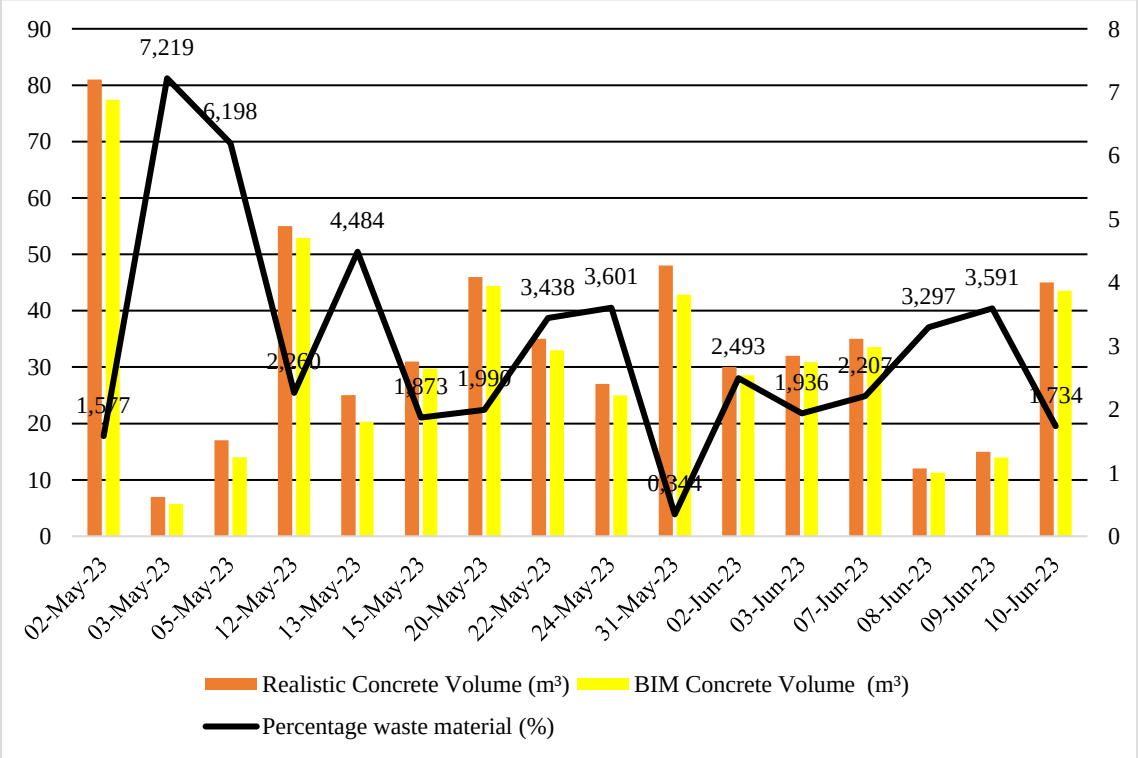

Figure 3. Percentage of *Waste Material* for Vertical Casting Work

Source: Personal Processed

Based on Figure 2 and Figure 3, the largest percentage of each casting job is obtained. The largest percentage for horizontal casting work is 3.133% with an average percentage of waste material for horizontal casting work of 2.192%. The largest percentage for vertical casting work is 7.219% with an average percentage of waste material for vertical casting work of 3.015%.

3.2 Waste Material Coefficient

The waste material coefficient is obtained by adding 1 m^3 to the known percentage of concrete waste material. This is because typically, 1 m^3 of concrete is required for 1 m^3 of casting work. When estimating the concrete volume requirement, contractors often multiply the volume by 10% to account for any wasted or spilled concrete during the batching plant mixing. However, during implementation, some waste materials need to be considered, as they go beyond this 10% calculation. As a result, it is necessary to analyze the coefficient of materials that already take waste material into account.

From the waste material analysis stage, the average percentage of waste material is obtained. For horizontal casting work, a value of 0.022 is obtained and for vertical casting work, a value of 0.03 is obtained. So that the waste material coefficient can be obtained, namely for horizontal casting of 1.022 and for vertical casting of 1.03. The value of 1 means that 1 m^3 of casting work requires 1 m^3 of concrete, while the values of 0.022 and 0.03 are the material loss factor values.

4. CONCLUSION

The volume of concrete requirements multiplied by 10% serves to anticipate any wasted or spilled concrete during mixing at the batching plant. However, in practice, this concrete does not fully cover the actual concrete needs in the field. The concrete volume should also be multiplied by the waste material coefficient. From the analysis results in this study, the average waste material for horizontal casting work is 0.022, and for vertical casting work, it is 0.03. Thus, the waste material coefficients can be obtained, which are 1.022 for horizontal casting and 1.03 for vertical casting. The waste material referred to in this study on the XYZ project pertains to waste material that cannot be physically identified. The waste material in the XYZ project includes instances where concrete adheres to connections like the concrete pump, bucket, and tremie pipe; concrete scatters due to loose pipe connections or exposure to wind during lifting; concrete gets stuck in the concrete pump; and instances where batching plant doesn't deliver concrete in the ordered quantity. This waste material coefficient is a coefficient of materials that accounts for waste material. In AHSP PerMen No. 1 of 2022, a coefficient value of 1.02 is mentioned for casting work using ready-mix concrete. Therefore, it's evident that the coefficient value in AHSP PerMen PUPR No. 1 of 2022 does not fully account for waste material in the field. The coefficient values analyzed in this study can serve as a reference for the project to adjust the coefficients in AHSP, aiding in planning concrete volume requirements as it considers real-world waste material. As a suggestion for future research, further studies are hoped to explore waste material coefficients for formwork and reinforcement works.

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