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Optimization of Ready-Mix Concrete Quality at PT Kalla Beton

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A B S T R A C T

Quality control from raw material to finished ready-mix concrete is vital in the construction industry, where increasing demand aligns with industry growth projected at 4% annually. PT Bumi Sarana Beton (Kalla Beton) faces challenges in maintaining consistent quality due to variations in natural raw materials, which impact product quality and cost. This research investigates the company's quality control strategies, focusing on optimizing material selection and mix designs. Experimental research methods were used, including testing different mix proportions and assessing compressive strength and production costs. The study involved aggregate suitability testing, redesigning concrete mixes with fly ash, and evaluating cost-effectiveness. Findings show that using fly ash improves compressive strength and reduces costs. The research concludes that refined material selection and mix design strategies can enhance product quality and cost efficiency. Recommendations include further exploration of alternative materials, and rigorous quality control to sustain high production standards and maintain competitive advantage in the ready-mix concrete market.

1. Introduction

Quality control from the raw material stage to marketed products is a crucial aspect of company operations, especially in the manufacturing industry for construction[1]. In this context, ready-mix concrete stands out as a highly demanded product in the market. The increasing demand for ready-mix concrete aligns with the growth of the construction industry and is projected to grow by 4% per years[2]. This Project presented significant challenges associated with using natural raw materials, which are the primary components in concrete production[3]. Natural raw materials, widely used in concrete mixtures, have a substantial impact on the quality and quantity of the final products [4]. However, limitations in natural resources and fluctuations in their quality can pose a major challenge in maintaining consistent quality standards that satisfy customers.

PT Bumi Sarana Beton (Kalla Beton), a company operating in the ready-mix concrete industry, faces similar challenges. To address quality control challenges on a production scale,

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the company needs to develop effective and measurable strategies. This research aims to examine the strategies implemented by PT Bumi Sarana Beton in controlling the quality of ready-mix concrete on a production scale. Practical and theoretical approaches will be used to comprehensively understand how the company manages quality control from raw material stages to marketed products. By deepening the understanding of the best strategies and practices implemented by PT Bumi Sarana Beton, this research is expected to provide valuable insights into the ready-mix concrete industry as a whole. Additionally, the findings of this research are anticipated to serve as a foundation for other companies facing similar challenges in maintaining competitive advantages and meeting customer expectations regarding product quality.

2. Research Method

Based on the objectives of this study, the research method employed is experimental research. This approach involves testing samples with various mix proportions at the batching plant to determine their impact on the quality of the ready-mix concrete. Initially, the established quality control measures will be implemented on a small scale to validate their effectiveness. These measures are derived from a comprehensive literature review of best practices and existing standards in the field.

3. Description and Technical

Aggregate Suitability Testing involves evaluating the properties of aggregates to ensure they meet the required standards for concrete production, utilizing techniques such as sieve analysis, specific gravity, and water absorption tests as per ASTM C33 standards. Compressive Strength and Production Cost Analysis of Existing Concrete entails assessing the compressive strength through ASTM C39 tests and analyzing production costs by materials. The Redesign of Concrete Mix focuses on developing a new mix design to enhance performance and cost-effectiveness, using SNI guidelines for mix proportioning and testing trial batches for slump and compressive strength. Implementation of Strategies involves applying the findings to improve concrete production, optimizing processes, and establishing quality control procedures.

1. Sampling Techniques.

The sampling techniques for testing fine and coarse aggregates refer to ASTM and SNI standards. In addition to sampling techniques, we also describe material acceptability references and acceptance criteria for materials. The data is presented in the following table.

Table 1. Standard References of Fine Aggregate Testing

Testing Type	Reference Standards for Testing		Acceptance Criteria
	Testing Method References	Acceptance References	
Sieve Analysis	ASTM C136 & SNI 1968:2010	ASTM C40 & SNI 2816:2014	Fine Modulus = 1.5-3.5 Chart result in limits
Organic Content	ASTM C136 & SNI 1968:2010	ASTM C33	Maximum No 3
SSD Specific Gravity	ASTM C128 & SNI 1970:2010	SNI 03-1969-2008	Minimum 2.5
Absorption	ASTM C128 & SNI 1970:2010	-	Maximum 4%
Water Content	ASTM C566 & SNI 1971:2011	-	-
Clay Content	ASTM C117 & SNI 03-4142-1996	ASTM C 33, SNI 8321:2016	Maximum 5%
Volume Weight	ASTM C29 & SNI 03-4804-1998	-	Minimum 1200 gram/liter

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Source: ASTM & SNI

Table 2. Standard References of Coarse Aggregate Testing

Testing Type	Reference Standards for Testing: Testing Method References	Reference Standards for Testing: Acceptance References	Acceptance Criteria
Sieve Analysis	ASTM C136 & SNI 1968:2010	ASTM C40 & SNI 2816:2014	Fine Modulus = 7.25-7.90 Result in graph limits
Los Angles Abrasion	ASTM C131 & SNI 03-4142-1996	ASTM C33	Maximum 40%
SSD Specific Gravity	ASTM C127 & SNI 1969:2016	SNI 03-1969-2008	Minimum 2.5
Absorption	ASTM C128 & SNI 1968:2010	-	Maximum 4%
Water Content	ASTM C566 & SNI 1971:2011	-	-
Clay Content	ASTM C117 & SNI 03-4142-1996	ASTM C 33, SNI 8321:2016	Maximum 5%
Volume Weight	ASTM C29 & SNI 03-4804-1998	-	Minimum 1200 gram/ liter

Source: ASTM & SNI

The methods for concrete planning, execution, and curing are based on Indonesian Standards (SNI). For planning, SNI provides comprehensive guidelines for designing concrete mix proportions to ensure that the mix achieves the required strength, workability, and durability for its intended use reference to SNI 7656:2012. We use the cylinder sample with the size 150 mm x 30 mm and for curing, SNI specifies methods to maintain proper moisture and temperature conditions, which are crucial for achieving optimal strength and durability of the concrete reference to SNI 4810:2013.

2. Definition of Variable Operations.

In this section, we will describe the variation codes to facilitate the concrete sampling. The samples used receive different treatments based on the descriptions provided in the table.

Table 3. Variance Code Description

Variance Code	Description
C0	Existing without Coarse Aggregate combination
C1	Existing Normal
C2	Redesign Normal
C3	Redesign with washing aggregate
C4	Redesign add Fly Ash 5%
C5	Redesign add Fly Ash 10%
C6	Redesign add Fly Ash 15%
C7	Redesign add Fly Ash 20%

Source: Laboratorium Kalla Beton, Makassar

The use of fly ash as an additive material aims to replace cement in the existing mix, which previously used concrete additives and an increased amount of cement (with a high safety factor). Fly ash is chosen due to its high economic value[5].

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4. Results and Discussions

4.1 Aggregate Suitability Testing

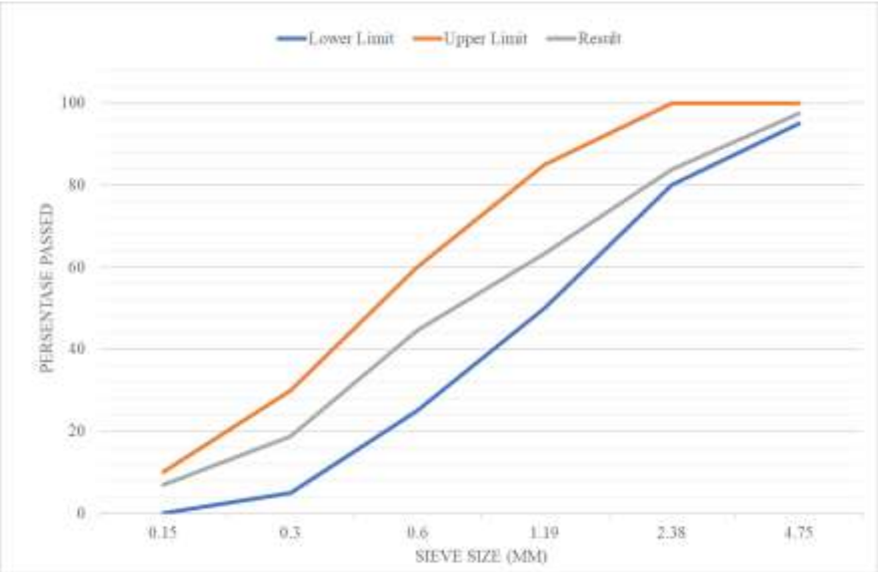
Aggregates make up approximately 70% to 80% of the overall volume of concrete[6]. As a result, aggregates have a significant impact on the designed compressive strength of concrete. The suitability of the aggregates used in the concrete mix is crucial for maintaining the quality of the concrete[7]. Therefore, this section will present field test data for the aggregates used at PT Kalla Beton.

1. Fine Aggregate

Table 4. Testing Results for Fine Aggregate

Testing Type	Results	Description
Sieve Analysis	1.95%	Passed
Organic Content	2	Passed
SSD Specific Gravity	2.83	Passed
Absorption	2%	Passed
Water Content	12.67%	Passed
Clay Content	7.41%	Didn't Passed
Volume Weight	1345 kg/m^3	Passed

Source: Laboratorium Kalla Beton, Makassar



Source: Test Result at the Laboratorium Kalla Beton

Figure 1. Graph of Fine Aggregate Sieve Test Results

The testing results in Table 4 of the fine aggregate used in the PT Kalla Beton batching plant indicate that most parameters meet the required standards, sieve analysis, organic content, specific gravity, absorption, water content, and volume weight. These results suggest that the aggregate is generally suitable for concrete production, contributing positively to its workability and strength. However, the clay content exceeded acceptable limits, which poses potential risks to the concrete's performance by affecting bonding and consistency. Addressing the high clay content is crucial to ensuring optimal quality in the final concrete mix, which may involve additional processing steps or sourcing alternative materials. Figure 1 illustrating the sieve analysis results demonstrates that the aggregate meets the standards outlined in ASTM C33, confirming its appropriate particle size distribution for concrete applications.

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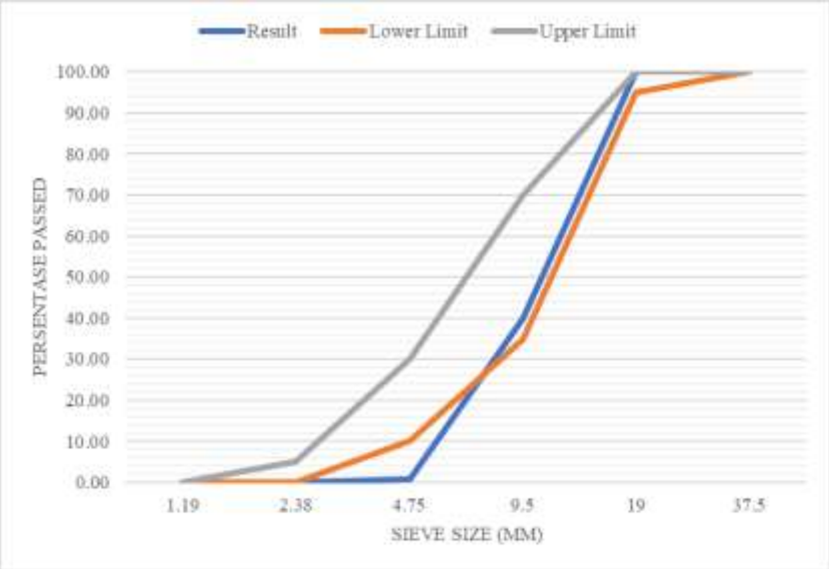
2. Coarse Aggregate

Table 5. Testing Results for Coarse Aggregate

Testing Type	Results	Description
Sieve Analysis	8.59%	Passed
Los Angles Abrasion	21.3%	Passed
SSD Specific Gravity	2.56	Passed
Absorption	0.8%	Passed
Water Content	2.74%	Passed
Clay Content	1.63%	Passed
Volume Weight	1457 kg/m^3	Passed

Source: Laboratorium Kalla Beton, Makassar



Source: Test Result at the Laboratorium Kalla Beton

Figure 2. Graph of Coarse Aggregate Sieve Test Results

The testing results for the coarse aggregate at PT Kalla Beton demonstrate that all parameters meet the required standards, confirming its suitability for concrete production. Key metrics shown in Table 5; Sieve analysis, Los Angeles abrasion, specific gravity, absorption, water content, clay content, and volume weight, all passed their respective tests. However, the coarse aggregate exhibits a size distribution shown in Figure 2, that does not conform to ASTM C33, which could potentially affect the compressive strength of the concrete. Addressing the size distribution issue is essential to ensure optimal concrete strength.

The aggregate suitability test data indicates that each type of aggregate has specific issues affecting material quality. The fine aggregate has a very high clay content, which can impact the compressive strength of the concrete because the concrete cannot bond properly[8]. Meanwhile, the coarse aggregate has a size distribution that does not conform to ASTM C33. This can also affect the compressive strength of the concrete[9].

4.2 Compressive Strength and Production Cost Analysis of Existing Concrete

Compressive strength is the most critical aspect prioritized in the production of ready-mix concrete. This fundamental property determines the load-bearing capacity and durability of the concrete, making it essential for ensuring the safety and longevity of structures [10]. In addition to compressive strength, as a provider of products and services, it is essential to implement effective strategies for managing production costs to remain competitive in the market. Efficient production cost management involves using cost-effective raw materials

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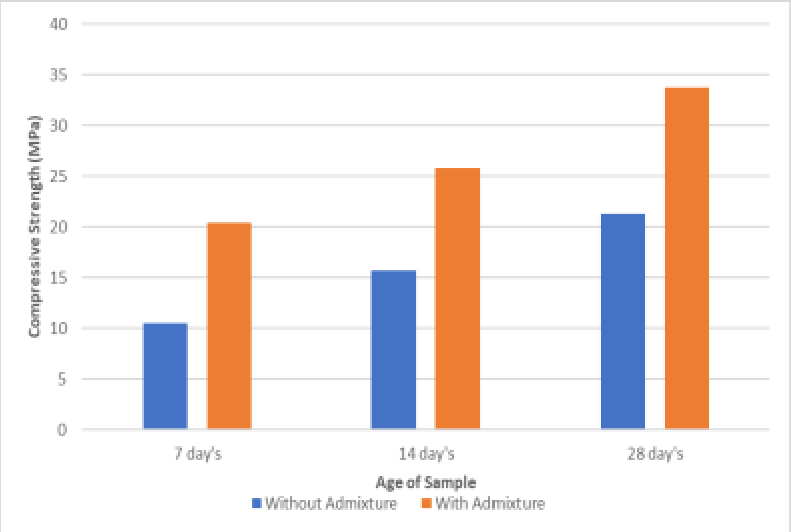
without compromising quality, optimizing production processes, and maintaining equipment properly to reduce downtime and increase productivity [11]. By doing so, the company can offer high-quality ready-mix concrete products at competitive prices, meeting customer needs while maintaining profitability and competitiveness in the construction industry.

We conducted a comprehensive analysis of both the compressive strength and the material costs necessary for producing the existing concrete. This dual analysis aims to ensure that the concrete not only meets the required strength specifications but is also cost-effective to produce. Simultaneously, by analyzing the material costs, our identifies opportunities for cost savings and efficiency improvements in the production process, ensuring the concrete remains competitive in the market without compromising on quality. The figure and table below present the analysis results data under existing conditions.



Source: Test Result at the Laboratorium Kalla Beton
Figure 3. Existing Compressive Strength

In the concrete mix with a planned compressive strength of 25 MPa, an optimum compressive strength of 33.69 MPa was achieved at 28 days when using admixture. This result indicates that the use of admixture significantly enhances the performance of the concrete, exceeding the planned compressive strength specifications. To determine the composition of materials used in their existing state, shown in the Table 6.

Table 6. Composition of material existing

Variance of Mixing	Water	Cement	Sand	Gravel	Admixture
	kg	kg	kg	kg	l
Without Admixture	160	400	848	1008	1.19
With Admixture	160	400	848	1008	0

Source: Laboratorium Kalla Beton, Makassar

The production cost for using materials in each cubic meter of concrete at PT Kalla Beton is Rp. 625,096.92 for concrete with a compressive strength of 25 MPa and a planned slump of 12 cm. This production cost can still be optimized by reducing the amount of cement used or replacing it with other materials, given that the current safety factor is quite high. This case is our focus, by implementing these adjustments, not only can costs be reduced, but the overall efficiency and sustainability of the concrete production process can be improved. This strategic approach can contribute to maintaining competitive pricing while ensuring the quality and performance of the concrete remains uncompromised.

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4.3 Redesign of Concrete Mix

Before redesigning the concrete mix, it is essential to first address and improve any materials that do not meet the required standards to ensure the desired quality and strength of the concrete. For instance, sand with a high clay content can significantly affect the performance of the concrete [12], [13]. To rectify this, one common approach is to add admixtures to the concrete mix. Admixtures can help mitigate the negative effects of impurities in the sand, enhancing the workability, strength, and durability of the final concrete product [14], [15].

The method of using admixtures for improvement has already been implemented at PT Kalla Beton to mitigate detrimental effects in the concrete mix. Therefore, the focus of the redesign is on utilizing more cost-effective materials. By incorporating economical materials, the goal is to achieve a balance between cost savings and maintaining the desired quality and performance of the concrete. This approach aims to enhance overall efficiency while ensuring that the concrete mix remains competitive in the market.

In line with improving efficiency without compromising the quality of the concrete products offered, we explored the potential of waste materials that can be used as additives in concrete, specifically fly ash. Fly ash was chosen as an additive due to its abundant availability and its feasibility for direct application. The use of fly ash can enhance the compressive strength of concrete and reduce the direct consumption of cement. By incorporating fly ash, we aim to achieve a more sustainable and cost-effective concrete mix while maintaining high standards of performance and durability [16], [17]. Additionally, the suboptimal utilization of fly ash at the Barru power plant serves as a supporting reason for us to explore its potential use.

Referring to the coarse aggregate suitability test in Figure 2, the sieve analysis results indicate that the size distribution of the aggregates does not meet the requirements specified in ASTM C33. Therefore, improvements to the coarse aggregate are necessary for its use. Before redesigning the mix, we performed adjustments using a graphical approach to achieve the appropriate coarse aggregate gradation [18], [19], [20]. This approach was implemented using the following equation:

$$Y = \frac{a}{100} ya + \frac{b}{100} yb$$

To calculate a comparison of the ideal combined coarse aggregate, use the equation:

$$a\% = \frac{\sum a}{4}$$

$$b\% = 100\% - a\%$$

When:

Y = Ideal specification for aggregate blending
a = Percentage of aggregate A in the blend
b = Percentage of aggregate B in the blend
ya = Percentage passing for aggregate A
yb = Percentage passing for aggregate B

The ideal combined percentage of coarse aggregate is shown the Table 7.

Table 7. Ideal Combined Coarse Aggregate

Sieve Size		Percentage Passing Aggregate A (%)	Percentage Passing Aggregate B (%)	Aggregate A in the Blend (%)	Aggregate B in the Blend (%)
Inchi	mm				
1.5	25.4	100	100	50	50
3/4	19	23.2	96	50	50
3/8	9.52	0	29.2	50	50
No 4	4.75	0	10.4	50	50
		Total		50%	50%

Source: Laboratorium Kalla Beton, Makassar

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Based on the calculations, 50% of existing coarse aggregate (A) and 50% of coarse aggregate B, which has a finer gradation, are required. After determining the ideal aggregate combination, the concrete mix design was carried out according to SNI 7656:2012. The material requirements for producing 9 test specimens for each mix variation are as follows, with a K value of 1.64 and a standard deviation of 3.5 for field conditions:

Table 8. Composition of Concrete Mix Materials

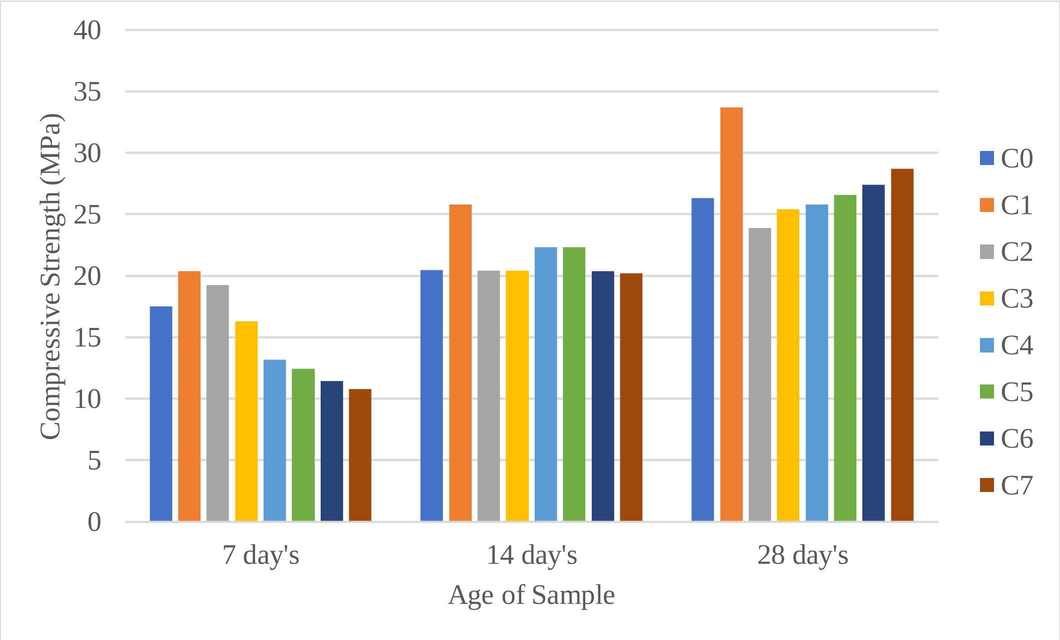
Variance Code	Water	Cement	Sand	Gravel A	Gravel B	Fly Ash	Admixure
	l	kg	kg	kg	kg	kg	l
C0	7.200	18.000	38.160	45.360	0	0	0.054
C1	7.200	18.000	38.160	32.999	31.383	0	0.054
C2	7.425	16.602	35.749	32.999	31.383	0	0
C3	7.425	16.602	35.749	32.999	31.383	0	0
C4	7.425	16.602	35.749	32.999	31.383	0.830	0
C5	7.425	16.602	35.749	32.999	31.383	1.660	0
C6	7.425	16.602	35.749	32.999	31.383	2.490	0
C7	7.425	16.602	35.749	32.999	31.383	3.321	0

Source: Laboratorium Kalla Beton, Makassar

In the concrete mix design, the coarse aggregate blending ratio of 50%:50% for aggregates A and B is determined based on their SSD specific gravity. This approach ensures an optimal mix of the desired properties. As a result, the actual weights required for coarse aggregates A and B differ, reflecting their specific densities and ensuring the mix achieves the necessary performance characteristics.

4.4 Compressive Strength

Compressive strength is the primary technical requirement that concrete must meet. Therefore, to ensure that the planned technical specifications are fulfilled, compressive strength testing is essential [21]. This testing also aims to analyze each mix variation that is deemed highly feasible for wide-scale implementation as a marketable product. The results of the compressive strength tests are presented in the figure.



Source: Test Result at the Laboratorium Kalla Beton

Figure 4. Concrete Compressive Strength Test Results

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Figure 4 shows the results of compressive strength tests on the test specimens. The test results indicate that each mix variation demonstrates good compressive strength performance. However, the mix variation C2 does not meet the planned compressive strength. The addition of fly ash to the new concrete mix achieves optimal compressive strength at 28 days. The inclusion of fly ash in the concrete mix is directly proportional to the compressive strength produced in the concrete mix.

4.5. Implementation of Strategies

Before devising an implementation strategy, it was essential to calculate the unit price for each mix that met the standards. Utilizing fly ash as an additive to replace admixture enabled a cost efficiency of Rp 13,685.00 in material usage per meter cubic mix concrete. This calculation laid the groundwork for the strategic steps PT Kalla Beton needed to take. First, securing a reliable and consistent supply of fly ash from local power plants, such as the Barru PLTU, was prioritized. Establishing partnerships and contracts with these suppliers ensured that the fly ash used in production was of high quality and readily available. Rigorous quality control measures were also implemented for incoming aggregates. This included regular testing to ensure they met the necessary specifications, particularly concerning clay content and gradation as outlined by ASTM C33 standards.

The use of admixtures continued to play a significant role in improving concrete properties, especially when dealing with fine aggregate that had a high clay content. Comprehensive training for technical staff on the proper use and benefits of admixtures was conducted to ensure effective application in all batches. This helped maintain the quality and performance of the concrete mix.

Next, the optimized mix designs, which incorporated fly ash and the ideal combination of coarse aggregates (50% aggregate A and 50% aggregate B), were gradually implemented. Pilot projects were launched to refine the mix design under real-world conditions, allowing for adjustments and improvements based on practical feedback. Standard Operating Procedures (SOPs) for the new mix designs were developed and enforced to ensure that the revised material proportions and mixing techniques were consistently applied across all production batches.

Enhancing production process efficiency was another critical step. Batching and mixing equipment were upgraded to handle the new mix designs efficiently, and automated batching systems were implemented to ensure precise measurement and mixing of materials. A comprehensive quality assurance program was established, including regular sampling and testing of concrete batches. This program ensured that the desired quality and performance of the concrete products were consistently met.

Furthermore, the cost savings achieved through the use of fly ash were reinvested into other areas of the production process. This included improving infrastructure, upgrading equipment, and investing in further research and development to explore additional cost-saving measures and performance enhancements. By taking these strategic steps, PT Kalla Beton effectively implemented the redesigned concrete mixes on a large scale, maintaining competitive pricing while ensuring high-quality concrete production. This approach not only improved efficiency and reduced costs but also contributed to the sustainability of the concrete production process.

5. Conclusion and Suggestion

5.1 Conclusion

To address the significant quality control challenges in the ready-mix concrete industry, PT Bumi Sarana Beton (Kalla Beton) has implemented strategic measures from raw material procurement to final product marketing. Given the industry's projected 4% annual growth and the increasing demand for ready-mix concrete, maintaining consistent quality despite the variability in natural raw materials is crucial. This research examines PT Kalla Beton's comprehensive quality control strategies, including the optimization of material selection, the use of fly ash as an additive, and the implementation of rigorous quality assurance programs.

The results from these strategies demonstrate notable improvements: the concrete mix with an optimal blend of materials achieved a compressive strength of 33.69 MPa, exceeding the planned specification of 25 MPa. Additionally, utilizing fly ash as an additive resulted in cost savings of Rp 13,685.00 per cubic meter of concrete. These measures not only enhance product quality but also contribute to sustainability and cost efficiency. The insights gained from this study are expected to benefit the broader industry, offering a foundation for other companies to improve their quality control practices and maintain competitive advantages.

5.1 Suggestion

To improve quality control and production efficiency for ready-mix concrete, we recommend conducting more in-depth research on alternative materials, such as different types of fly ash, to refine mix designs for optimal performance and cost-effectiveness. Implementing advanced automation and process optimization algorithms can ensure consistency and reduce human error in production. Additionally, establishing continuous training programs for technical staff on the latest advancements in concrete technology will support the maintenance and enhancement of production standards.

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