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Feasibility Analysis of a Batching Plant for Concrete Production in the Kediri-Tulungagung Toll Road Project

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ABSTRACT:
The Kediri-Tulungagung Toll Road Project necessitates high-quality concrete production to meet the rigorous specifications outlined by Indonesia's Ministry of Public Works and Housing. This study focuses on evaluating the feasibility of an on-site batching plant in producing concrete that complies with the specified quality standards for freeways and toll roads. Using the Job Mix Design method and referring to SNI 03-2834-2000, the research examines the plant's ability to consistently achieve the desired concrete quality. Data on material properties, production costs, and operational efficiency were collected and analyzed through a mixed-methods approach, integrating qualitative and quantitative data. The findings confirm that the plant meets the required technical specifications, achieving a compressive strength of 30 MPa to 50 MPa, with over 90% of samples exceeding quality benchmarks. Additionally, the investment analysis reveals cost savings of approximately 15% compared to external suppliers, making it economically viable. The integration of modern technologies, such as computerized mixing systems and effective waste management practices, supports sustainability goals by reducing carbon emissions and recycling concrete waste. This study provides crucial insights and practical recommendations for implementing internal batching plants in large-scale infrastructure projects, offering a sustainable and cost-effective solution for reliable concrete production.

Keywords: Concrete quality, batching plant, feasibility study, toll road construction, Job Mix Design

INTRODUCTION

The need for high-quality concrete is increasing along with the rapid development of infrastructure, especially for freeway or toll road projects. Concrete has become the main material used in various infrastructure projects due to its strength, resistance to pressure, and flexibility in forming. Toll road construction projects require concrete with certain specifications that meet the required quality and strength standards. The Ministry of Public Works and Housing

(PUPR) stipulates that the quality of concrete for toll roads must comply with the applicable Indonesian National Standards (SNI) (National Standardization Agency, 2000; 2004; 2016). These standards are designed to ensure that the materials used have resistance to various loads and extreme environmental conditions that often occur in road infrastructure.

To ensure project sustainability and efficiency, in-house batching plants have become a strategic solution. The internal batching plant is a concrete mixing facility that is managed directly by the project implementer. According to research by Rani et al. (2020), internal batching plant management can improve cost and time efficiency by minimizing dependence on third parties and maximizing control over the quality of concrete produced. The implementation of in-house batching plants allows for more flexible management, especially in meeting the specific needs of high-grade concrete for large-scale projects such as toll roads.

In the concrete mixing process, each component plays an important role. The ideal concrete composition consists of a mixture of cement, fine aggregate, coarse aggregate, water, and certain additives such as superplasticizers to improve performance. Dr. Edward G. Nawy (1990) explains that the characteristics of concrete-forming materials must be well understood to produce high-quality concrete. For example, Portland cement and slag cement that conform to national standards can provide optimal mechanical properties and durability to concrete (Indonesian National Standardization Agency, 2004; 2016). In addition, the aggregates used must meet the requirements of size, hardness, and cleanliness, while the amount of water must be sufficient for the hydration reaction without exceeding the limit that can reduce the strength of the concrete.

Freeway projects require concrete of varying grades, ranging from fc' 10 MPa for minor works to fc' 50 MPa for major structural elements such as rigid pavements, abutments, and piers. Research by Foulhudan et al. (2022) shows that precise calculations in the proportioning and mixing of materials are essential to achieve the required compressive strength of concrete. Therefore, regular quality monitoring is required at every stage of production, from mixing to field application.

In addition, the issue of sustainability is a major concern in the modern construction industry. The use of green concrete, or environmentally friendly concrete, is one solution to reduce the environmental impact of carbon emissions generated during the concrete production process. Research by Rohman et al. (2023) shows that green concrete, which uses recycled or alternative materials, can help reduce the carbon footprint without compromising quality. In internal batching plants, concrete waste management, such as the reutilization of wastewater and unused concrete scraps, is an important step to support project sustainability (Martins et al., 2022).

The quality of the concrete produced also depends on the mixing method used. Modern mixing methods, such as vibrated concrete (VC) and self-compacting concrete (SCC), provide different results according to project needs. Abdulmalek and Chakkamalayath (2023) emphasized the importance of cost-benefit analysis in choosing a mixing method. VC, for example, requires specialized tools to mechanically compact the concrete, whereas SCC has the ability to flow and compact itself without the aid of tools. In internal batching plants, the selection of mixing methods can be customized to meet the needs of a particular project by considering efficiency, quality, and cost.

In addition to the technical aspects, investment in an internal batching plant also requires a comprehensive feasibility analysis. This analysis includes the calculation of Net Present Value (NPV), Internal Rate of Return (IRR), and Payback Period to determine if the investment is financially viable. According to research by Rani et al. (2020), in-house batching plants provide long-term benefits in the form of reduced production costs and improved quality control. However, factors such as equipment depreciation costs, maintenance costs, and risk of operational failure must also be taken into account. Kaya (2023) added that investment feasibility evaluations need to be conducted periodically to ensure project sustainability and resource optimization.

With the growing demand for high quality concrete for highway projects, internal batching plants offer a solution that is not only efficient but also able to support sustainability and innovation. These advantages make internal batching plants an integral part of modern infrastructure development strategies. In the future, further research on technological innovations in batching plants is expected to contribute significantly to meeting the need for high-quality concrete while minimizing environmental impact.

RESEARCH METHODS

This study uses a qualitative descriptive approach with quantitative data analysis to evaluate the effectiveness of internal batching plants in meeting the needs of high-grade concrete. This method was chosen to provide an in-depth description of the batching plant management, concrete production process, and factors affecting quality. This approach also allowed the researcher to identify challenges and solutions in batching plant operations according to the Ministry of PUPR's 2020 specifications.

The data collected includes primary data from direct observation at the batching plant site and interviews with experts. In addition, secondary data was obtained from related literature, such as research journals and national standard documents. Data analysis was conducted systematically to integrate findings from various sources.

The research was conducted at an internal batching plant used in a freeway project with the Ministry of PUPR specifications in 2020. This location was chosen due to its operational relevance in producing high-grade concrete. The study utilized data from a project that has been in operation for one year to ensure the validity of the results.

The research sample includes concrete production data from the batching plant, specifications of the materials used, and documentation of the production process. In addition, interviews were conducted with batching plant operators, project managers, and engineers to gain technical and managerial perspectives related to batching plant management.

Data collection was conducted through direct observation, interviews, and document studies. Direct observation included monitoring the material mixing process, equipment operation, and waste management. In-depth interviews were conducted to understand the challenges and solutions in batching plant operations. Document study involved analyzing technical specifications, production reports, and national standards, such as SNI 03-2834-2000 and SNI 7656:2012. Quantitative data in the form of production volume, concrete quality, and operational costs were collected to support further analysis.

Data analysis was conducted using a mixed approach, combining descriptive and statistical analysis. Qualitative data was analyzed to identify key patterns and themes related to batching plant management. Quantitative data, such as concrete compressive strength and production cost, were processed using descriptive statistics to provide an overview of batching plant performance. The results of the analysis were compared with technical specifications set by the Ministry of PUPR and national standards. This comparison aims to evaluate the extent to which the internal batching plant is able to meet the needs of high-grade concrete according to the specifications.

Validation was done through triangulation of data from various sources, such as observations, interviews, and document studies. This step aims to ensure the accuracy and consistency of the findings. Interviews with experts in concrete and construction management were used to confirm the analysis results. In addition, the research results were compared with findings from previous studies to identify congruence or differences. This process helped to ensure that the conclusions drawn were well-founded and relevant to best practices in the management of batching plants for freeway projects.

RESULTS AND DISCUSSION

Production Capacity and Quality of Concrete

The internal batching plant used in the Ministry of Public Works and Housing's 2020 expressway project has sufficient production capacity to meet the needs of high-grade concrete. With an average daily concrete production of 300 cubic meters, the facility is designed to produce concrete with compressive strength specifications ranging from 30 MPa to 50 MPa, depending on the specific needs of the construction elements being worked on. This production process has met the quality standards stipulated in SNI 03-2834-2000, which requires strict testing of concrete compressive strength. Based on the test data, more than 90% of the concrete samples meet or even exceed the set technical specifications, indicating a very high level of reliability.

In-house batching plant operations provide various advantages, especially in quality control. The material mixing process is carried out under close supervision using modern technology, such as computerized systems that ensure each batch of concrete has a uniform composition. This technology enables precise formulation adjustments, resulting in consistent concrete quality. In addition, the selection of high-quality raw materials, such as Ordinary Portland Cement (OPC) cement and coarse aggregate with the right gradation, is a determining factor in the success of producing high-quality concrete. These efforts are also supported by continuous monitoring to ensure that the materials used meet the set quality standards.

Aside from the quality aspect, the in-house batching plant provides high flexibility in meeting concrete volume requirements. In emergency situations or project acceleration, production capacity can be increased up to 400 cubic meters per day without compromising product quality. This flexibility is a significant plus, allowing projects to run on schedule without the risk of delays. In the context of large-scale projects such as toll road construction, timeliness is a key success factor. With an in-house batching plant, consistent concrete supply needs can be met with high efficiency, supporting the completion of the project on time and in accordance with the desired technical specifications.

Cost Efficiency and Waste Management

In addition to ensuring optimal concrete quality, operating an internal batching plant has also proven to be more economical. The cost of concrete production per cubic meter at the in-house batching plant averages at IDR 850,000, much lower than the price of concrete from external suppliers which reaches IDR 1,000,000 per cubic meter. These savings, which amount to about 15%, are mainly obtained from the full control of the entire production process, from material selection to operational management. Thus, in-house batching plants not only provide benefits in terms of quality but also make a real contribution to cost efficiency in large-scale infrastructure projects.

Sustainability is also a major concern in the internal batching plant operations, especially in waste management. Waste generated in the form of sludge and concrete residue is recycled using advanced technology for reuse in the production of non-structural concrete. With this approach, the waste generated is not only significantly reduced, but also provides economic benefits by reducing operational costs. A study conducted by Martins et al. (2022) showed that concrete waste management with recycling methods can increase efficiency by up to 20%, confirming the importance of this approach in supporting the sustainability of the construction industry.

The use of environmentally friendly additives, such as admixtures with low carbon technology, is also part of the sustainability strategy. These admixtures help reduce carbon emissions by 18%, in line with the emission reduction target set by the Ministry of PUPR. In addition, the internal batching plant is equipped with a dust control system designed to minimize the impact on the surrounding environment. The system works by filtering dust particles before they are released into the air, keeping the air quality in the operational area good and environmentally friendly.

The commitment to sustainability is also reflected in other measures taken by the batching plant managers. Efficient use of resources, from water to energy, is part of the effort to reduce the environmental footprint. In addition, periodic training to operators and other staff at the batching plant is conducted to ensure that the entire team has a high awareness of environmentally friendly practices. These measures are taken to ensure that the operation of the batching plant not only produces high quality concrete but also supports sustainable development goals.

In freeway projects involving internal batching plants, the benefits are not only limited to technical and economic aspects, but also include social and environmental dimensions. By integrating modern technology and sustainable practices, the internal batching plant has demonstrated that efficiency and sustainability can go hand in hand. This is an operational model that can be adopted in other projects, not only in the toll road sector but also in other areas of infrastructure. Thus, the in-house batching plant not only acts as a practical solution in meeting the needs of high quality concrete but also as an example of how innovation and sustainability can be harmoniously integrated in the world of construction.

Table 1. Sand Sieve Analysys Test

Sample Type: Sand						**Date: July 30, '24**		
Sample Weight: 1000 grams						**Material: Ex - Blitar**		
No.	***SIEVE NUMBER***	***SIEVE SIZE* (mm)**	**STAY**			**LOLOS**		
			Gram	**%**	**Comulative**	**%**	**Min (%)**	**Max (%)**
1	**1"**	**25**						
2	**¾"**	**19**						
3	**½"**	**12.5**						
4	**3/8"**	**9.5**	**0**	**0**	**0**	**100**	**100**	**100**
5	**No.4**	**4.75**	**52**	**5.2**	**5.2**	**94.8**	**95**	**100**
6	**No.8**	**2.36**	**82**	**8.2**	**13.4**	**86.6**	**80**	**100**
7	**No.16**	**1.18**	**219**	**21.9**	**35.3**	**64.7**	**50**	**85**
8	**No.50**	**0.3**	**553**	**55.3**	**90.6**	**9.4**	**10**	**30**

9	**No.100**	**0.15**	**76**	**7.6**	**98.2**	**1.8**	**2**	**10**
10	**Pan**	**0**	**18**	**1.8**	**100**	**0**	**0**	**0**

Source: Researcher Processed Data 2024

The internal batching plant is a strategic solution in meeting the needs of high quality concrete that meets the specifications of the PUPR freeway in 2020. The main advantage of internal batching plants is the ability to control the entire production process, from raw material selection to concrete quality testing. By utilizing modern technology, the internal batching plant can ensure that each batch of concrete has high consistency and quality. This is especially important in freeway projects that require concrete with strict specifications, such as a minimum compressive strength of 40 MPa for the main structural elements.

The use of an internal batching plant provides significant flexibility in adjusting production capacity according to project needs. Under normal conditions, the batching plant is capable of producing up to 300 m³ of concrete per day. However, in emergency conditions or when there is a sudden increase in demand, the production capacity can be increased to up to 400 m³ per day. This capability ensures that the project remains on schedule, even when there are changes in the concrete needs in the field. This flexibility is a competitive advantage for freeway projects that have tight deadlines and require a high speed of execution.

In addition to production flexibility, the in-house batching plant also offers more efficient material management. Raw materials such as cement, aggregates, water and additives are carefully organized to avoid wastage. This management system reduces the risk of overstocking that can lead to losses, while maximizing the use of the available materials. This efficiency in material management not only reduces production costs but also supports the smooth running of the overall construction process.

From a sustainability perspective, the in-house batching plant demonstrates a strong commitment to environmental management. Concrete waste generated during the production process is managed using recycling technology, so that the waste can be reused in the production of non-structural concrete. This measure not only reduces the negative impact on the environment but also results in operational cost savings. In addition, the use of environmentally friendly additives, such as low-carbon admixtures, helps reduce carbon emissions generated during the concrete production process. These efforts are in line with global goals to support sustainable development and reduce the impact of climate change.

The results show that internal batching plants are able to make a positive contribution to the efficiency of construction projects. This finding is consistent with the previous study by Rohman et al. (2023), which highlighted the importance of using green batching plants in supporting the sustainability of construction projects. In the study, it was concluded that good batching plant management can improve production efficiency while minimizing environmental impacts. With the strategies implemented, the internal batching plant can serve as a model for similar projects in the future, especially in terms of efficiency and sustainability.

The advantages of internal batching plants are not only limited to technical and environmental aspects. From an economic point of view, the use of internal batching plants can save up to 15% of concrete production costs compared to purchasing concrete from external suppliers. This is due to the process integration that allows full control over the entire production chain, from raw material procurement to concrete distribution to the project site. With these significant cost savings, freeway projects can allocate more budget to other important aspects, such as traffic management during construction and installation of road safety elements.

The integrated process in the in-house batching plant also ensures that concrete requirements can be met on time and to specification. This is key to the success of large-scale construction projects, such as freeways, which often face logistical and operational challenges. With an in-house batching plant, projects can minimize the risk of delays caused by concrete supply mismatches, so that project completion targets can be achieved according to the planned schedule.

The successful implementation of the internal batching plant in this freeway project was also supported by good collaboration between the project management team and the batching plant operators. Training and improving the competence of the workforce is one of the main focuses to ensure that the entire production process runs smoothly. With a trained and experienced workforce, the possibility of errors in the production process can be minimized. In addition, the use of advanced technology such as automatic monitoring systems and production management software provides a high level of accuracy in every stage of concrete production.

Effective waste management is one of the most important aspects of operating an internal batching plant. The concrete waste generated is not only recycled into non-structural building materials, but also used for other needs, such as soil filler or base material for non-structural road construction. This recycling process supports the principle of circular economy, where waste is converted into useful resources, thereby reducing dependence on new raw materials. Thus, the internal batching plant not only contributes to cost efficiency but also supports environmental sustainability in the long run.

In the face of global challenges, such as climate change and increasing infrastructure needs, in-house batching plants can be an innovative strategic solution. By adopting green technology and a data-driven approach, in-house batching plants are able to adapt to future needs. For example, the use of additives such as low-carbon admixtures not only reduces the carbon footprint but also improves the performance of concrete under extreme conditions, such as high temperatures or aggressive environments.

The implementation of the internal batching plant also has a positive impact on the local community. By utilizing local resources for raw materials, the project can provide economic benefits to the surrounding community. In addition, good waste management and the use of clean technology help maintain the quality of the living environment around the project site. These measures show that the internal batching plant is not only oriented towards project success but also towards social and environmental responsibility.

In conclusion, the internal batching plant is a superior solution to meet the needs of high-grade concrete in accordance with the technical specifications of PUPR. The advantages in quality control, production flexibility, cost efficiency, and good waste management make it the right choice for large-scale construction projects. With an integrated and sustainable approach, the in-house batching plant not only supports the success of the project but also makes a positive contribution to the environment and society. Therefore, this model can be widely adopted in future infrastructure projects as part of the effort to achieve inclusive and environmentally sustainable development.

Conclusion

The feasibility analysis of the batching plant for the Kediri-Tulungagung Expressway Project shows very positive results from various aspects. In terms of quality, the facility is able to produce high quality concrete with 90% of samples meeting the standards of the Ministry of PUPR. Economically, there is a 15% saving with a production cost of IDR 850,000 per cubic meter compared to external suppliers. Flexible production capacity (300-400 m3/day), effective waste management system with sludge recycling for non-structural concrete, as well as the use of modern technology such as computerized system and dust control, prove that the in-house batching plant is the right solution to meet the needs of the project in terms of quality, cost efficiency, and environmental sustainability.

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