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Article

Factors Causing Delays in Building Projects (Case Study of Norva Husada Maternity and Children's Hospital)

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A B S T R A C T

Construction project delay is a condition where the execution of work does not proceed according to the agreed schedule. The construction project of Norfa Husada Mother and Child Hospital experienced delays impacting costs and operational time. This study aims to identify the factors causing delays, determine the most dominant factors, and formulate preventive measures. The method used was a questionnaire distribution to 30 respondents directly involved in the project, including contractors, consultants, and project owners. Data were analyzed using descriptive statistics (Mean Rank) with SPSS software. The results show that the Planning Factor is the most dominant cause, specifically due to design changes (redesign) and changes in the scope of work, with a mean value of 1.97. The second dominant factor is the Execution Factor, particularly regarding poor work sequence planning, with a mean value of 1.90. Based on these results, the main strategies to prevent delays include maturing the design planning before construction begins, strengthening coordination between the owner and contractor regarding scope changes, and establishing a more structured method of execution (SOP) in the field.

1. Introduction

The rapid growth of the construction industry in Indonesia has increased the demand for building materials that are efficient, economical, and environmentally friendly. Lightweight bricks have become a popular alternative because they have lower density, faster installation, and can reduce structural loads compared to conventional clay bricks. Lightweight bricks are generally classified into two types, namely Autoclaved Aerated Concrete (AAC) and Cellular Lightweight Concrete (CLC). Among these, CLC bricks are more widely applied because their production does not require special equipment such as autoclaves and the curing process can be carried out naturally, making them suitable for small- to medium-scale production.

At the same time, Indonesia faces environmental challenges due to the increasing volume of biomass waste from the palm oil industry. As one of the largest palm oil producers in the world, Indonesia generates large amounts of palm kernel shell waste, which is commonly used as boiler fuel and produces palm kernel shell ash. The utilization of this ash is still limited, and improper management may cause environmental problems. In palm oil–producing regions such as Riau Province, the availability of palm kernel shell ash is abundant and offers potential for use as an alternative material in construction applications.

Palm kernel shell ash contains silica (SiO_2) and alumina (Al_2O_3), which exhibit pozzolanic properties and can contribute to cementitious reactions. These characteristics indicate that palm kernel shell ash has potential as a supplementary material in cement-based products, including CLC lightweight bricks. Therefore, this study aims to investigate the effect of palm kernel shell ash as a cement additive on the properties of CLC bricks, focusing on unit weight, water absorption, and compressive strength, in order to support sustainable construction materials and the effective utilization of palm oil industry waste.

2. Literature Riview

2.1 Understanding Lightweight Bricks

Lightweight bricks or what are commonly called foamed concrete are materials made from mortar mixed with foam agents by arranging the foam mixture into lightweight bricks, so that they have a weight ranging between 600-1800 kg/m3, so that one of the advantages of lightweight bricks is that they are lighter than ordinary bricks.

2.2 Light Brick Type

The commonly known types of lightweight bricks are divided into two, namely Autoclaved Aerated Concrete (AAC) and Cellular Lightweight Concrete (CLC). The difference between AAC and CLC lightweight bricks in terms of the drying process is that AAC is dried in a high-pressure autoclaved oven while the CLC type undergoes a natural drying process. CLC is often referred to as Non-Autoclaved Aerated Concrete (NAAC). Although AAC has better compressive strength and lower shrinkage than CLC, but at a lower cost, CLC can be designed with compressive strength equal to AAC. Therefore, the use of CLC is more popular than AAC.

2.3 Materials Composing Lightweight Bricks

The basic materials used to form lightweight bricks are cement, sand, and a foaming agent. Generally, bricks are composed of two components: a binder and a filler. Cement and water act as binders, with the cement hydrated by water binding the fine aggregate, while the aggregate, consisting of sand and other aggregates, acts as the brick's filler.

2.4 Palm Kernel Shell Ash

An admixture is a material other than the main concrete component that is added to the concrete mixture during mixing in a certain amount to change the concrete's properties. The function of these materials is to change its properties to make it suitable for a particular job, economical, or for other purposes such as saving energy.

Table 1. Chemical Element Content of Palm Oil Shell Ash

Parameter	Result	Method
Silica (SiO_2)	33.12 %	Gravimetric
Iron Oxide (Fe_2O_3)	0.10 %	AAS
Calcium Oxide (CaO)	3.03 %	AAS
Aluminium Oxide (Al_2O_3)	5.59 %	Spectrophotometry

2.5 Aggregate Inspection

Fine aggregate inspection is carried out to determine the properties and characteristics of the fine aggregate to be used so that it can be known what treatment must be carried out in the future so that it can be used as a concrete component.

2.6 Mixed Planning

The mix design for lightweight bricks refers to the Ministry of Public Works in 2014 (Suryanita, 2020), which is carried out by calculating the cement and water requirements in 1 m^3 of the mixture based on the weight and specific gravity of each material. Next, the volume of the sand and foam mixture is determined, then the planned sand and foam requirements are calculated according to the planned percentage. The total weight of all materials is adjusted to the planned density, and from this composition, the cement, sand, water, and foam requirements for making test samples are calculated based on the total volume of the test object.

3. Research Methodology

3.1 Research Design

This study is a study that uses an experimental method to determine the relationship between the effect of ACKS as a cement substitute in lightweight bricks on the specific gravity, water absorption and compressive strength of lightweight bricks. The percentage of cement replacement by ACKS used is 0%, 4%, 6% and 8%, of the weight of cement. The cement used in the study is Portland cement produced by PT. Semen Padang. For the fine aggregate used in the study was taken from the river in Batu Belah village, Kampar District, Kampar Regency, Riau Province. The test object used in the study was a block-shaped test object with dimensions of 15 × 20 × 60 cm.

The research conducted was quantitative, with the primary instrument being the researcher himself, through descriptive notes during the study. These notes were obtained through activities such as interviews with sources, observation, documentation, literature review, and other means.

3.2 Research Location

The research was conducted at the Engineering Laboratory of Pahlawan Tuanku Tambusai University.

Figure.1 Research Location

3.3 Data Collection Procedures

Data collection was conducted through several methods. Secondary data was obtained directly during testing, such as fine aggregate inspection, specific gravity testing, water absorption testing, and compressive strength testing. Secondary data was obtained from Indonesian National Standards, journals, books, final projects, and other sources relevant to the current research. The data collection procedure is carried out as follows:

1. Fine Aggregate Inspection
2. Mixing Procedure
3. Lightweight Brick Mortar Printing Procedure
4. Light Brick Mold Removal Procedure
5. Lightweight Brick Maintenance
6. Bulk Density and Water Absorption Testing
7. Compressive Strength Testing of Lightweight Bricks

4. Results and Discussion

4.1 Fine Aggregate Testing

Fine aggregate testing for lightweight brick mixes was conducted at the Engineering Laboratory of Pahlawan Tuanku Tambusai University. The testing was conducted in accordance with SNI (Indonesian National Standardization) for each test. Fine aggregate testing included specific gravity testing, sieve analysis testing, mud content testing, and organic content testing. The results are as follows:

1. Content weight testing

The bulk density test was conducted to determine the material's mass per unit volume under loose and compacted conditions. This parameter is essential in civil engineering applications, as bulk density significantly influences stability, bearing capacity, and material efficiency in construction works.

Based on the results of the loose condition bulk density test presented in Table 4.1, the bulk density values for Samples I, II, and III were 1.3956 kg/L, 1.3725 kg/L, and 1.3697 kg/L, respectively, with an average value of 1.3793 kg/L. These results indicate that the material in a loose condition has a relatively low density due to the presence of a considerable amount of air voids between particles. The variation among the samples is relatively small, suggesting that the tested material exhibits good homogeneity under loose conditions.

Meanwhile, the compacted condition bulk density test results shown in Table 4.2 yielded bulk density values of 1.5525 kg/L, 1.5417 kg/L, and 1.5577 kg/L, with an average value of 1.5506 kg/L. The increase in bulk density under compacted conditions is attributed to the compaction process, which reduces the air voids within the material, resulting in a denser particle arrangement and a higher mass per unit volume.

A comparison between the loose and compacted bulk density values shows an average increase of 0.1713 kg/L, equivalent to approximately 12.4%. This increase indicates that the material responds well to compaction, suggesting its potential to provide improved structural performance when applied in the field. Such characteristics are particularly important for construction works that require adequate compaction levels, such as embankments and base course layers.

4.2 Specific Gravity Testing

The test of specific gravity and water absorption of fine aggregate was conducted in accordance with SNI 1970:2016 to determine the physical characteristics of the fine aggregate used in the mix design of lightweight bricks. The parameters evaluated included bulk specific gravity (dry), saturated surface-dry (SSD) specific gravity, apparent specific gravity, and water absorption.

Based on the test results of two fine aggregate samples, the average bulk specific gravity (dry) value was 2.5232. This value indicates that the fine aggregate has adequate density and falls within the typical range of normal-weight aggregates, which is approximately 2.5–2.7. The bulk specific gravity in dry condition represents the aggregate without water in its pores and is an important parameter for determining aggregate proportions in dry conditions during mix design.

Furthermore, the average saturated surface-dry (SSD) specific gravity was 2.5776, which is higher than the dry bulk specific gravity because, in the SSD condition, the aggregate pores are filled with water while the surface remains dry. The SSD specific gravity plays a crucial role in mix design calculations, particularly in determining the required mixing water to ensure proper workability and to avoid excessive or insufficient water content, which may affect the strength and quality of lightweight bricks.

The test results also showed an average water absorption value of 2.1557%. This value is within the acceptable limit for fine aggregates, which generally should not exceed 3%. A relatively low water absorption indicates that the aggregate has moderate porosity, thereby reducing the risk of excessive water demand in the mixture. However, the variation in absorption values between Sample 1 and Sample 2 suggests differences in aggregate particle characteristics, such as gradation, particle shape, or surface texture.

Meanwhile, the average apparent specific gravity was 2.6704, which is higher than both the bulk and SSD specific gravity values. This is because apparent specific gravity does not account for the volume of permeable pores within the aggregate. The apparent specific gravity reflects the density of the solid aggregate material and indicates that the fine aggregate has a relatively dense and stable particle structure.

4.3 Sieve analysis testing

The sieve analysis test of fine aggregate was conducted in accordance with SNI 1968:1990 to determine the particle size distribution and gradation characteristics of the fine aggregate used in lightweight brick production. Based on the test results, the percentages of retained and passing material were obtained for sieve sizes ranging from No. 4 to No. 200. The results indicate that the fine aggregate exhibits a relatively well-distributed particle size composition, with a significant proportion of particles retained on sieve No. 16, No. 30, and No. 100, suggesting the dominance of medium to fine-sized particles.

The fineness modulus (FM) obtained from the sieve analysis was 2.938, which classifies the fine aggregate as medium to slightly coarse sand. The fineness modulus is an important parameter affecting the workability, water demand, and density of the mixture. A fineness modulus value close to 3 generally indicates a stable gradation, which contributes to better particle interlocking and denser mixtures, thereby potentially improving the quality and mechanical performance of lightweight bricks.

According to the fine aggregate gradation zones specified in SNI 03-2834:2002, a fineness modulus of 2.938 places the tested aggregate in Zone II. This gradation zone is commonly recommended for concrete and lightweight concrete products due to its balanced proportion of fine and coarse particles. Therefore, it can be concluded that the fine aggregate used in this study meets the gradation requirements and is suitable for use in lightweight brick production, as it supports good mix stability and the achievement of the desired material properties.

4.4 Sludge Content Testing

The clay content test of fine aggregate was conducted in accordance with SNI 03-4428:1997 to determine the presence of clay and colloidal particles attached to the aggregate. Based on the test results from three samples, the average sand height was 11.133 cm, while the average clay height was 0.2 cm. The calculation results show that the average clay content of the fine aggregate was 1.755%, indicating a relatively low and consistent amount of clay across all tested samples.

This clay content value is below the maximum allowable limit of 5% for fine aggregate, indicating that the aggregate meets the standard requirements. A low clay content is essential because excessive clay can interfere with the bond between aggregate particles and the binder, as well as increase water demand in the mixture. Therefore, the fine aggregate used in this study is considered suitable for use in lightweight brick production, as it is unlikely to adversely affect the strength, quality, and durability of the final product.

4.5 Organic Content Testing

Organic content testing refers to SNI 2816-2014 (National Standardization Agency, 2014). The organic content results are obtained by comparing the color of the 3% NaOH solution in which the fine aggregate is immersed with the color number on the organic plate. In this test, color number 2 is obtained. From the test, it can be concluded that the organic content of the fine aggregate used in this study is low, and good aggregate is suitable for use in lightweight brick composition.

4.6 Mix Design

The mix design of foamed mortar in this study was carried out at the laboratory scale to achieve a target density of 1100 kg/m^3, which is a key characteristic of lightweight bricks. The mix proportion was determined using a water–cement ratio of 0.50 and a planned cement content of 300 kg/m^3. Based on volumetric calculations, the required water content was 150 kg/m^3, resulting in cement and water volumes of 0.095 m^3 and 0.15 m^3, respectively. The remaining mixture volume of 0.7548 m^3 was filled by a combination of fine aggregate and foam agent to achieve the desired lightweight properties.

The fine aggregate requirement was set at 31.41% of the remaining mixture volume, with an SSD specific gravity of 2.5776, resulting in a sand content of 611.07 kg/m^3. Meanwhile, the foam agent accounted for 68.59% of the remaining volume, with a foam density of 0.075 kg/m^3, producing a foam requirement of 38.83 kg/m^3. The verification of the total mixture weight yielded a value of 1099.90 kg/m^3, which closely matches the target density of 1100 kg/m^3, indicating that the proposed mix design satisfies the planned density requirement.

For specimen preparation, the volume of one sample was 0.018 m^3, with an additional 20% safety factor, resulting in a total mixture volume of 0.2592 m^3 per variation. Accordingly, the material requirements per variation consisted of 77.76 kg of cement, 38.88 kg of water, 158.39 kg of sand, and 10.06 kg of foam agent. In addition, an additive material (ACKS) was incorporated at variations of 0%, 4%, 6%, and 8% by weight of cement to evaluate its effect on the properties of lightweight bricks. The use of ACKS is expected to modify the characteristics of foamed mortar, particularly in enhancing mechanical performance and microstructural quality, without significantly altering the target density.

4.7 Mix Planning, Manufacturing, and Maintenance of Lightweight Bricks

The mix planning, production, and curing of lightweight bricks in this study were conducted in accordance with the guidelines of the Ministry of Public Works (2014) to ensure consistent quality and performance. All constituent materials, including cement, fine aggregate, water, foam agent, and the additive material (ACKS), were prepared and mixed based on the predetermined mix proportions. The mixing process was carried out gradually until a homogeneous foamed mortar was obtained, particularly during the addition of the foam agent, as uniform air-void distribution plays a crucial role in controlling density and structural stability of the lightweight bricks.

The foamed mortar was then cast into cube molds that had been coated with oil to facilitate demolding. After casting, the specimens were placed in a stable environment, free from vibration and external disturbances, to prevent segregation and collapse of the pore structure during early setting. Curing was performed using the water curing method for three consecutive days, with watering conducted three times per day to maintain adequate moisture for cement hydration. This curing procedure was intended to enhance early strength development and minimize the risk of early-age cracking, thereby ensuring that the lightweight bricks exhibit optimal physical and mechanical properties.

4.8 Bulk Density and Water Absorption Testing

The density and water absorption tests of lightweight bricks were conducted in accordance with SNI 8640:2018 to evaluate the physical properties of lightweight bricks with ACKS additions of 0%, 4%, 6%, and 8% at testing ages of 7, 14, 21, and 28 days. Based on the test results, the density values generally exhibited variations with increasing curing age and ACKS content. For the mixture without ACKS (0%), the density tended to decrease from 7 to 28 days, indicating the development of pore structure due to cement hydration and internal moisture loss. In contrast, mixtures containing ACKS showed fluctuating density values, suggesting that the presence of ACKS influenced the microstructure and pore distribution within the foamed mortar matrix.

The water absorption results showed an increasing trend with higher ACKS content, particularly at the ages of 21 and 28 days. The mixture without ACKS exhibited lower water absorption values compared to the mixtures with ACKS, indicating a relatively denser and less permeable pore structure. Conversely, higher ACKS contents (6% and 8%) resulted in increased water absorption, which can be attributed to the formation of a more open and interconnected pore system. This condition suggests that excessive ACKS content may increase porosity and permeability of lightweight bricks.

4.9 Compressive strength testing

The compressive strength test of lightweight bricks in this study was conducted in accordance with SNI 8640:2018 to evaluate the mechanical performance of the specimens at different curing ages and ACKS contents. The test was performed at 7, 14, 21, and 28 days using a hydraulic compression testing machine, with a controlled loading rate of approximately 0.1 MPa/s until failure occurred. The specimens were prepared in the form of cubes with dimensions of 150 mm × 150 mm × 150 mm, and the load was applied on the flat surface corresponding to the thickness side of the brick to ensure uniform stress distribution during testing.

The results indicate that the compressive strength of lightweight bricks is influenced by several factors, including curing age and mixture composition, particularly the percentage of ACKS addition. In general, compressive strength increased with increasing curing age due to the continued cement hydration process, which enhances the bonding within the foamed mortar matrix. Variations in compressive strength among different ACKS contents suggest that the additive affects the microstructure of the lightweight bricks by altering pore distribution and interparticle bonding. At higher ACKS contents, the potential increase in porosity may reduce strength gains, highlighting the importance of determining an optimal ACKS dosage.

The observed failure patterns of the specimens, especially at early ages, were characterized by gradual cracking and crushing, which is typical of lightweight, porous materials.

This behavior confirms that the compressive strength of lightweight bricks is governed not only by the strength of the cement paste but also by the stability and uniformity of the pore structure formed by the foam agent and modified by ACKS addition. Therefore, optimizing the ACKS content is essential to achieve a balance between lightweight characteristics and adequate compressive strength in accordance with applicable standards.

5. Conclusion

Based on the results of material characterization and experimental testing, it can be concluded that the fine aggregate used in this study met the requirements of the applicable Indonesian Standards (SNI), as indicated by acceptable values of specific gravity, gradation, and clay content. The mix design of foamed mortar was successfully developed to achieve a target density of 1100 kg/m³, and verification results showed that the planned density was closely attained. The incorporation of foam agent effectively reduced the density of the bricks, while the addition of ACKS influenced the internal pore structure and physical properties of the lightweight bricks.

The test results of density, water absorption, and compressive strength demonstrated that curing age and ACKS content significantly affected the performance of the lightweight bricks. In general, compressive strength increased with curing age due to the ongoing hydration process, while higher ACKS contents tended to increase water absorption, indicating higher porosity. Although the addition of ACKS contributed to variations in density and strength, excessive ACKS content showed a tendency to reduce performance due to increased pore connectivity. Therefore, an optimal ACKS dosage is required to achieve a balance between lightweight characteristics, acceptable water absorption, and sufficient compressive strength.

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