The Effect of Sodium Silicate (Na_2SiO_3) Addition against Water Absorption and Compressive Strength in Bricks

M. Abdi Ridha
Universitas Al-Azhar Medan, Medan, Indonesia

Corresponding Author: abdiridha1919@gmail.com

Abstract

This study investigates the impact of Sodium Silicate (Na_2SiO_3) addition on the water absorption and compressive strength of bricks, aiming to enhance understanding of material properties in construction. Sodium Silicate was incorporated into the brick mix at concentrations of 0%, 10%, 20%, and 30% by weight of cement, with a mix ratio of 1:7 (cement). The compressive strength and water absorption tests were conducted after a 28-day curing period, following the Indonesian National Standard (SNI) procedure 03-0349-1989. The results indicate that increasing Sodium Silicate concentration led to a decrease in compressive strength, with values of 45.62 MPa, 50.27 MPa, and 59.03 MPa observed at 10%, 20%, and 30% addition levels, respectively, compared to the control (standard bricks). Conversely, water absorption increased by 0.79%, 1.47%, and 2.31% at these respective concentrations. The observed reduction in compressive strength is attributed to the gel-like and adhesive properties of Sodium Silicate, which potentially hinder uniform water distribution within the brick matrix, thereby affecting the overall material performance. These findings suggest that while Sodium Silicate can enhance water resistance in bricks, its use at higher concentrations may compromise structural integrity. Further research is recommended to optimize the concentration of Sodium Silicate for balanced mechanical properties and durability in brick production.

Keywords: Bricks, Sodium Silicate, Compressive Strength, Water Absorption

I. Introduction

In ancient times, building construction used burnt bricks and then developed into using bricks [1] [2]. Brick is a brick-shaped concrete used to install walls. Its primary materials are Portland cement, fine aggregate sand, and water [3][4]. Compressive strength depends on the properties of individual building units (i.e., brick and mortar), slenderness ratio, thickness of mortar joints, and construction control followed by masons [5] [6]. The problem is that bricks are often damaged due to high water absorption, which affects the compressive strength of the bricks. Today's obstacle is that the quality of bricks that is not uniform between brick makers is the main reason bricks are less desirable than red bricks [7] [8]. In addition to non-uniform quality, bricks are more expensive than red bricks [9] [10]. Even in terms of brickwork, it is more efficient because of its large shape and easy installation. This problem makes practitioners and the world of education continuously research to get bricks that are of better quality but still economical [11] [12] [13] state that the quality of bricks is determined based on the ratio of constituent materials of cement and sand mixture as in table 1:

Table 1 Brick Quality is Based on the Cement and Sand Ratio

No	Quality	Ratio Cement & Sand		
1	Common	1	:	12
2	Standard	1	:	10
3	Premium	1	:	7

Source [13]

According to SK SNI S-04-1989-F, concrete bricks are categorized into two distinct types based on their structural composition: solid and perforated. Solid concrete bricks are characterized by a cross-sectional area of at least 75% solid, meaning that the solid part of the brick's cross-section makes up three-quarters or more of the total cross-sectional area. Additionally, the solid volume of these bricks exceeds 75% of the total brick volume, showing that most of the brick's material is solid. On the other hand, perforated concrete bricks feature a cross-sectional area where more than 25% consists of holes or voids, and the volume of these perforations also surpasses 25% of the total brick volume. This distinction emphasizes that perforated bricks are designed with significant voids to reduce material usage or improve thermal performance. In addition to these classifications, SNI 03-0349-

1989 further categorizes the quality of concrete bricks based on their physical properties, explicitly distinguishing between hollow and solid bricks. Hollow bricks typically have perforations or cavities and are often used in applications where reduced weight or improved insulation is desired. Solid bricks, by contrast, are more commonly used in load-bearing applications due to their higher strength and durability. These classifications provide a framework for understanding the different types of concrete bricks available and their respective uses in construction, ensuring that the appropriate brick type is selected based on the specific needs of a building project [14][15].

Table 2 Physical Requirements for Solid Bricks based on SNI 03-0349-1989

Physical Requirements	Unit	Quality of Solid Concrete Brick			
		I	II	III	IV
Average min, Gross compressive strength.	$\frac{Kg}{cm^2}$	100	70	40	25
The test specimen, min, Gross compressive strength.	$\frac{Kg}{cm^2}$	90	65	35	21
Average Water Absorption max.	%	25	35	-	-

Table 3 Physical Requirements for Perforated Bricks based on SNI 03-0349-1989 [16]

Physical Requirements	Unit	Quality of Solid Concrete Brick			
		I	II	III	IV
Average min, Gross compressive strength.	$\frac{Kg}{cm^2}$	70	50	35	20
The test specimen, min, Gross compressive strength.	$\frac{Kg}{cm^2}$	65	45	30	17
Average Water Absorption max.	%	25	35	-	-

Figure 1 Solid Brick

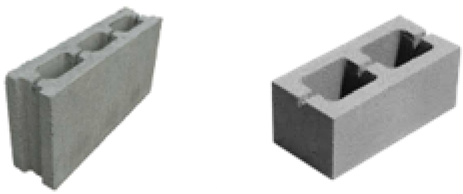

Figure 2 Perforated Bricks

Since brick is brick-shaped concrete, several efforts to improve the quality of concrete by using *additives* are also applied in making bricks [17] [18]. Common additives used to increase compressive strength and improve porosity in concrete[19] [20]*"from rice husks (hulk ash), red brick powder, methacholine, and silica fume and sodium silicate (Na_2SiO_3)"* [21]. In this study, the author used *sodium silicate (Na_2SiO_3)* as an added material mixed in the mixture of brick makers to see its effect on the compressive strength and permeability of the bricks produced. Research on the use of additives *sodium silicate (Na_2SiO_3)* to improve concrete quality has often been carried out, such as by P Giannaros states that sodium silicate (Na_2SiO_3) can react to the calcium hydroxide content $Ca(OH)_2$ found in hydrated cement paste, formed then calcium silicate hydrate $3CaO2SiO_23H_2O$ (C-S-H) in the form of a gel that is insoluble in water, which can fill the pores of the concrete, so that which can further compact concrete, and increase the level of waterproofness and compressive strength[22] [23] [24]. The $3CaO2SiO_23H_2O$ (C-S-H) content formed has the same properties as concrete, so a perfect bond occurs in concrete. Another study on the use of *sodium silicate (Na_2SiO_3)* as an added material in concrete mixtures was also carried out [25] [26].

In a study entitled "*Evaluation of Concrete Durability Performance with Sodium Silicate Impregnates*" concluded that concrete impregnated with sodium silicate significantly increased performance on compressive strength, porosity, permeability, and resistance to chloride compounds. From this explanation, this problem can be solved by increasing the brick's compressive strength and reducing water absorption by adding *sodium silicate* *(Na_2SiO_3)*. This study aims to obtain data and information about the influence of understanding *sodium silicate* *(Na_2SiO_3)*. There is the absorbency of bricks and their compressive strength, which will later be the development of knowledge for a mixture of brick aggregates that have good strength.

II. Method

The method used in this study is an experimental method of analysis where brick material is examined on the effect of adding *sodium silicate* *(Na_2SiO_3)* on water absorption and strength, and a literature review is conducted to determine the reason for the importance of this research [27]. Bris, in this case, are made manually through iron plate molds measuring 20 x 10 x 40 cm. Bri s are made based on a mixture ratio of 1 7 (cement: sand) [28][29]. The mixture is added to *sodium silicate* *(Na_2SiO_3)* with a concentration of 10%, 20% to 30% by weight of cement. Furthermore, a compressive strength test and the water absorption power within the brick life were carried out 28 days after manufacture [30]. The test procedure uses SNI-03-1968-1990. Here is a flow diagram from this study:

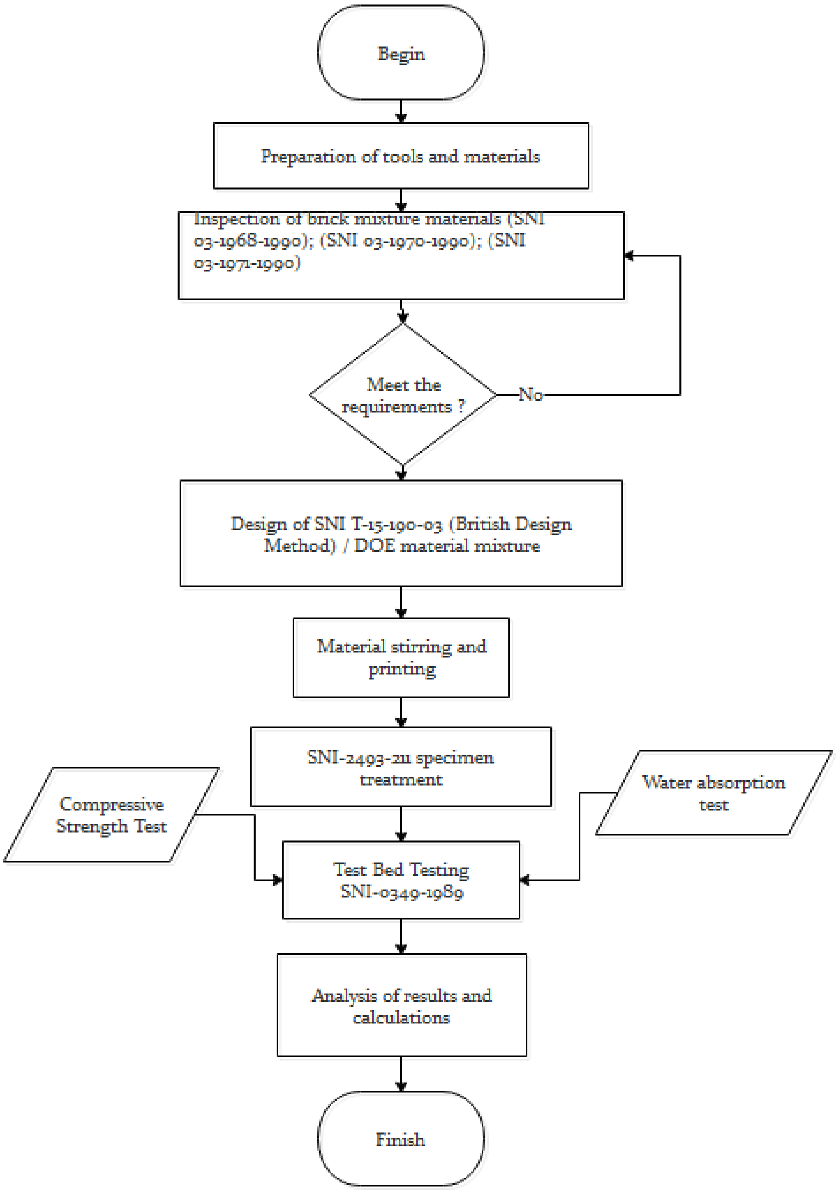

Figure 3 Flow Chart of Research Stages

Figure 3 describes the process carried out in this study. This research begins with preparing the test material, and then a compressive test is carried out with a predetermined standard; if it is improper, the material preparation process is repeated. The conformity process of existing standards (British Design Method) and stirring of the material are to be printed, where water absorption and strength tests are carried out for bricks that have been printed.

Figure 4 Physical Form of *Sodium Silicate (Na_2SiO_3)*

III. Results and Discussion

A. The Physical Form of Sodium Silicate (Na_2SiO_3)

The fine aggregate in the brick mixture is analyzed according to the stipulated SNI provisions. The results of the material inspection can be seen in the following table 4:

Table 4 Results of a Fine Aggregate of Brick Mix Materials

Types of Analysis	Results	Parameters
Grain Fine Modulus (MHB)	3.57	1.5 – 3.8
Types of aggregate gradations	Rude	
Specific Gravity		
- Bulk specific gravity	2.51	2.5 – 2.7
- SSD (Saturate Surface Dry)	2.53	2.5 – 2.7
- Pseudo (appearance)	2.60	2.5 – 2.7
- Absorption (%)	0.81	Max 3%
Sludge Content (%)	3.57	< 5%
Weight of Dropsy Volume $\left(\frac{g}{cm^3}\right)$	1,44	1,4 – 1,9
Weight of Solid Volume $\left(\frac{g}{cm^3}\right)$	1,64	1,4 – 1,9
Specific Gravity of Cement $\left(\frac{g}{cm^3}\right)$	3.15	3.0 – 3.2

B. The Proportion of Brick Mix Material (Mix Design with DOE Method)

The British DoE method is commonly used to obtain concrete designed using cement and aggregates per the relevant British Standards. Concrete designs with a compressive strength of 75 MPa and a lifespan of 28 days are not suitable for this method, and concrete designs containing fly ash and GGBFS are not suitable [31]. From the results of laboratory analysis of fine aggregate, the proportion of mixed materials that make up bricks can be calculated as follows:

1. *Brick Net Volume:*

Calculating the net volume of bricks is needed to estimate the number of bricks needed in the construction; this is important because the wrong situation makes planning not go well and incur greater costs. The calculation is:

= brick size – cavity volume
= brick size - (1/2 Base x height x length)
= 40 x 20 x 10 cm – (1/2 x 3 x 2 x 80 cm)
= 8000 cm^3 – 240 cm^3
= 7760 cm^3

2. *The Volume of Cement per Brick:*

The volume of cement per brick is used to calculate the amount of cement needed to produce one brick; this calculation is obtained after calculating the net weight of the brick and then multiplied by the weight of the cement volume:

= 1/8 x 7760 cm3 x weight of cement volume
= 1/8 x 7760 cm3 x 3.15 gr/cm^3
= 3.055 g = 3.05 kg

3. *Volume of Sand per Brick:*

Calculating the amount of sand needed to make one brick is a calculation to get the amount of sand needed to make one brick; calculating the net weight of bricks figures out this calculation.

= 7/8 x brick net volume x sand volume weight
= 7/8 x 7760 cm^3 x 1.44 g/cm^3
= 9777.6 g = 9.7 Kg

4. *Water Volume per Brick:*

The amount of water needed for one brick is calculated by calculating the number of FAS (cement water factor); the smaller the amount of FAS used, the better the bricks are produced. The number of FAS used is 0.71 and uses the volume of cement per brick.

= FAS Value x Cement Volume Weight
= 0.71 x 3.05
= 2.165 Kg
= 2.165 Kg x 0.753 = 1.63 Liters

The FAS value of 0.71, obtained from the following graph, by:

a. Compressive Strength determined (Fc') = 10 Mpa (according to brick physical standards according to SNI)
b. Margin (M):
   = 1.64 x standard deviation
   = 1.64 x 4.2
   = 6.8 Mpa
c. Value of Compressive Strength Plan (f'c):
   = f'c + M
   = 10 Mpa + 6.8 Mpa
   = 16.8 Mpa (168 Kg /cm^2)

The FAS value is figured out by taking a cut line between the plan's compressive strength value (168 Kg/cm^2) and the test object's 28 days of life, obtaining an FAS value of 0.71. The figure below shows that the compressive strength of 168 MPa when a linear line is used is obtained by FAS 0.71. is ed for the relationship between compressive strength and cement water factor[32].

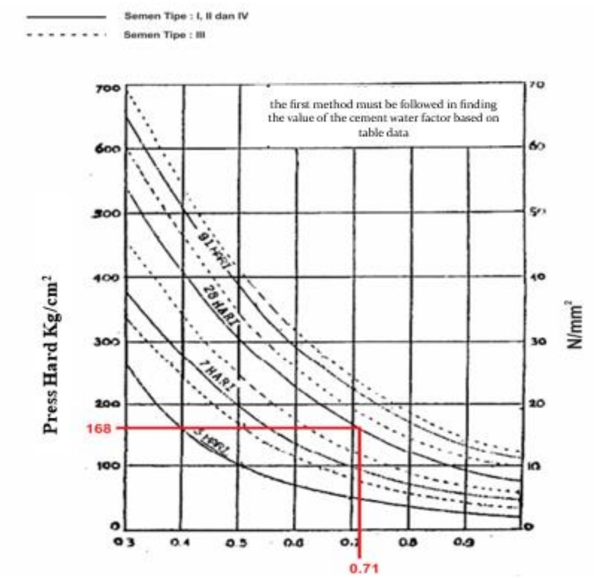

Figure 5 Relationship between Compressive Strength and Water Factor of Cement

Table 5 Sodium Silicate Requirement per Brick

No	Sodium Silicate	Vol. Cem t (kg)	Na_2SiO_3 /Brick (Kg)
1	Control - 0%	3.05	0
2	Concentration - 10%	3.05	3.05 x 10% = 0.305
3	Concentration - 20%	3.05	3.05 x 20% = 0.61
4	Concentration - 30%	3.05	3.05 x 30% = 0.91

Table 5 explains the variables of research conducted with four (4) treatments, namely the concentration of 0.10, 20.30%, and the volume of cement, which is 3.05, so that the weight of the brick is obtained, which is the multiplication of the concentration of Na_2SiO_3 and the volume of cement.

C. Compressive Strength Test Results on 28 Days Bricks

The compressive strength test results of bricks used with the British DoE method use four types of bricks with average brick composition and the addition of Na_2SiO_3 with a percentage of 10.20 and 30%. The est results can be seen in the table.

Table 6 Compressive Strength Test Results of 28 Days Bricks

No.	Sample Description	Compressive Strength (Kg/Cm^2)
1	Normal Bricks (control)	74.24
2	Brick + Na_2SiO_3 10%	28.62
3	Brick + Na_2SiO_3 20%	23.97
4	Brick + Na_2SiO_3 30%	15.21

The results of compressive strength testing show that the higher the concentration of sodium silicate (Na_2SiO_3), the lower the compressive strength of the brick.

D. Water Absorption Test Results on 28 Days Bricks

The results of the water absorption test on 28-day-old bricks were carried out to figure out the effect of adding Na_2SiO_3 on water absorption needed for compressive strength testing on the composition of the bricks as seen in table 7.

Table 7 Compessive Strength Test Results of 28 Days Old Brick

No.	Sample Description	Water Absorption (%)
1	Normal bricks (control)	3.41
2	Brick + Na_2SiO_3 – 10%	4.20
3	Brick + Na_2SiO_3 – 20%	4.88
4	Brick + Na_2SiO_3 – 30%	5.72

Table 7 above shows that the higher the concentration of sodium silicate (Na_2SiO_3) added to the brick mixture, the greater the brick's water absorption capacity.

The inspection results of the fine aggregate used in the brick mixture indicate that the materials conform to the standards specified by the Indonesian National Standard (SNI). The rain fine modulus (MHB) of 3.57 falls within the acceptable range of 1.5 to 3.8, suggesting an appropriate particle size distribution for adequate compaction and strength. Spe fic gravity values, including bulk (2.51), SSD (2.53), and pseudo (2.60), align with the standard range of 2.5 to 2.7, indicating that the aggregate possesses adequate density and is not overly porous. The low absorption rate of 0.81% suggests that the aggregate has minimal water absorption capacity, which is beneficial for maintaining the strength and durability of the bricks. Furthermore, the sludge content is 3.57%, below the 5% maximum threshold, ensuring that the fine aggregate does not contain excessive impurities that could compromise the brick's structural integrity.

The compressive strength tests on bricks modified with varying concentrations of sodium silicate (Na2SiO3) reveal that increasing Na2SiO3 content negatively affects the compressive strength of the bricks. As served in the results, regular bricks without Na2SiO3 exhibit a compressive strength of 74.24 kg/cm², while bricks with 10%, 20%, and 30% Na2SiO3 concentrations show a significant decrease in strength to 28.62 kg/cm², 23.97

kg/cm², and 15.21 kg/cm², respectively. This trend suggests that higher concentrations of Na2SiO3 reduce the cohesion within the brick matrix, potentially due to the formation of a weaker bond or altered microstructure, leading to diminished load-bearing capacity. The British DoE method's application underscores the significance of maintaining an optimal balance between aggregate composition and additive concentrations to ensure the desired compressive strength and durability.

Additionally, water absorption tests indicate that the inclusion of Na2SiO3 increases the water absorption capacity of the bricks. Nor l bricks (control) have a water absorption rate of 3.41%, while those with 10%, 20%, and 30% concentrations of Na2SiO3 exhibit progressively higher absorption rates of 4.20%, 4.88%, and 5.72%, respectively. The increased water absorption may be attributed to the altered porosity or microstructure caused by sodium silicate addition, which could facilitate greater water uptake. High r water absorption rates can adversely affect the long-term durability of bricks, especially in environments exposed to moisture, as they may lead to degradation and reduced compressive strength over time. These findings emphasize the need to carefully optimize Na2SiO3 concentrations to balance water resistance and mechanical properties.

IV. CONCLUSION

From the results of this study, it was found that (Na_2SiO_3) ≥ 10% can reduce compressive strength and increase the water absorption of bricks for 28 days. The high concentration of sodium silicate (Na_2SiO_3) added is directly proportional to the deterioration in the quality of the bricks. It happens because of the physical properties of sodium silicate (Na_2SiO_3), which is jelly-shaped and adherent. If it mixes with water, there will be an increase in water viscosity. Change becomes an obstacle in the water that dissolves all other materials. The rise in viscosity results in cement not hydrolyzing evenly, which results in low binding strength between materials in the brick mixture. This is what causes the compressive strength of the brick to decrease. The contribution of this research is to provide knowledge that the addition of sodium silica Na_2SiO_3 causes a decrease in the compressive strength of bricks and increases water absorption so that in the future, it is expected to be able to conduct further research on the proportion of sodium silica Na_2SiO_3 in the cement mixture. The implications of this study provide scientific information for future research so that there is no need to add too much sodium silica Na_2SiO_3 to the cement brick mixture. The imitations in this study were the addition of Na_2SiO_3 with variations of 10,20 and 30%, as well as testing the compressive strength of bricks. The following research is the most effective composition of Na_2SiO_3 to increase brick compressive strength and refine brick quality by adding Na_2SiO_3 with the Taguchi method.

ACKNOWLEDGEMENTS

The researcher extends his sincere gratitude to the Study Program of Civil Engineering at Universitas Al-Azhar Medan for generously providing the facilities that were instrumental in conducting this research. The researcher also deeply appreciates Mr. Mawardi, the Dean, for his invaluable support and funding, which significantly contributed to the successful execution of this study.

REFERENCES

[1] A. Srisuwan and N. Phonphuak, "Physical property and compressive strength of fired clay bricks incorporated with paper waste," *J. Met. Mat. Miner.*, vol. 30, no. 1, pp. 103–108, 2020, doi: 10.14456/jmmm.2020.12.

[2] H. Prayuda, F. Monika, and M. D. Cahyati, "Fresh properties and compressive strength of self compacting concrete with fines aggregate replacement using red brick powder and rice husk ash," *World J. Eng.*, vol. 17, no. 4, pp. 473–480, 2020, doi: 10.1108/WJE-08-2019-0236.

[3] L. Fatmawati, L. Supriono, and D. N. Amadi, "Pelatihan pembuatan batako desa Jatimulyo Kecamatan Kauman Kabupaten Tulungagung Lokal," *J. Daya-Mas*, vol. 6, no. 1, pp. 33–39, 2021, doi: 10.33319/dymas.v6i1.59.

[4] Dedyerianto, L. O. Asmin, and L. Isa, "Effect of Addition of Used Tire Aggregate and Glass Bottle Waste on Characteristics and Compressive Strength of Brick," *J. Multidisiplin Madani*, vol. 2, no. 3, pp. 1139–1150, 2022, [Online]. Ava able: https://journal.yp3a.org/index.php/mudima/index

[5] Y. Xiong, G. Xu, D. Wu, S. Fang, and Y. Tang, "Investigation of using the ceramic polishing brick powder in engineered cementitious composites," *J. Build. Eng* vol. 43, no. Mar 2021, doi: 10.1016/j.jobe.2021.102489.

[6] M. Mishra, A. S. Bhatia, and D. Maity, "Predicting the compressive strength of unreinforced brick masonry using machine learning techniques validated on a case study of a museum through nondestructive testing," *J. Civ. Struct. Hea Mon .*, vol. 10, no. 3, pp. 389–403, 2023, doi: 10.1007/s13349-020-00391-7.

[7] A. Saiz, "Bricks, mortar, and proptech: The economics of IT in brokerage, space utilization and commercial real estate finance," *J. Prop. Inv t. Fin c.*, vol. 38, no. 4, pp. 327–347, 2020, doi: 10.1108/JPIF-10-2019-0139.

[8] A. Lasa, Y. Pulinggomang, and I. Astuti, "Analisis pengendalian kualitas produk batako pada UKM Indra Batako di desa Oeltua Kecamatan Taebenu Kabupaten Kupang," *J. Bisnis Manaj.*, vol. 14, no. 2, pp. 189–200, 2022, [Online]. Available: https://ejurnal.undana.ac.id/index.php/JBM/article/view/9502

[9] U. E. Edike, O. J. Ameh, and M. O. Dada, "Production and optimization of eco-bricks," *J. Clean. Pro*, vol. 266, p. 121640, 2020, doi 10.1016/j.jclepro.2020.121640.

[10] G. Rori, D. R. O. Walangitan, and R. L. Inkiriwang, "Analisis perbandingan biaya material pekerjaan pasangan dinding bata merah dengan bata ringan," *J. Sipil Statik*, vol. 8, no. 3, pp. 311–318, 2020, [Online]. Available: https://ejournal.unsrat.ac.id/v3/index.php/jss/article/view/28749

[11] M. Khan and M. Ali, "Optimization of concrete stiffeners for confined brick masonry structures," *J. Build. Eng* vol. 32, no. Jul p. 101689, 2020, doi: 10.1016/j.jobe.2020.101689.

[12] K. Kurniawan, P. Prihantono, and R. Saleh, "Pemanfaatan Limbah Kotoran Sapi Sebagai pengganti sebagian semen dalam pembuatan batako," *Menara J. Tek. Sipil*, vol. 15, no. 2, pp. 53–57, 2020, doi: 10.21009/jmenara.v15i2.14214.

[13] S. Aprilyanti and F. Suryani, "Penerapan desain eksperimen taguchi untuk meningkatkan kualitas produksi batu bata dari sekam padi," *J@ti Undip J. Tek. Ind.*, vol. 15, no. 2, pp. 102–108, 2020, doi: 10.14710/jati.15.2.102-108.

[14] R. Rumbayan and Sudarno, "Kuat tekan, kuat lentur dan daya serap air untuk batako dengan penambahan serat sabut kelapa," *J. Polimdo*, vol. 2, no. 3, pp. 48–57, 2020, doi: 10.47600/jtst.v2i3.255.

[15] P. Lumbantoruan, H. Prasetio, and Rahmawati, "Kemampuan variasi campuran sekam padai pada batako terhadap peredaman suhu," *J. Deform.*, vol. 7, no. 2, pp. 174–183, 2022, doi: 10.31851/deformasi.v7i2.9176.

[16] W. Gustika Hami, A. Alfa, and R. Kinanda, "Pengaruh campuran serat kulit pinang dan serbuk gergaji terhadap kuat tekan batako," *Selodang Mayang J. Ilm. Badan Perenc. Pembang. Drh. Kabupaten Indragiri Hilir*, vol. 7, no. 2, pp. 69–76, 2021, doi: 10.47521/selodangmayang.v7i2.209.

[17] H. R. Gavali and R. V. Ralegaonkar, "Design development of sustainable alkali-activated bricks," *J. Build. Eng* vol. 30, no. Feb ary, p. 101302, 2020, doi 10.1016/j.jobe.2020.101302.

[18] S. Harahap, "Analisa perbandingan biaya serta waktu pelaksanaan meterial dinding batu bata dan batako pada rumah type 36," *Educ. Dev.*, vol. 9, no. 3, pp. 20–26, 2021, doi: 10.37081/ed.v9i3.2645.

[19] M. Alae, Y. Zhao, S. Zarei, G. Fu, and D. Cao, "Effects of layer interface conditions on top-down fatigue cracking of asphalt pavements," *Int. J. vement Eng.*, vol. 21, no. 3, pp. 280–288, 2020, doi: 10.1080/10298436.2018.1461870.

[20] D. Ardiansyah, Y. Amran, and S. U. Dewi, "Optimasi sifat fisik dan mekanis batako menggunakan sekam padi," *TAPAK (Teknologi Apl. Konstr. J. Progr. Stud. Tek. Sipil*, vol. 11, no. 1, p. 67, 2021, doi: 10.24127/tp.v11i1.1800.

[21] S. Suhaimi and M. Mujibullah, "Variasi penambahan Fly Ash terhadap kuat tekan beton," *J. Rekatek Univ. Almuslim*, vol. 5, no. 1, pp. 10–17, 2020, [Online]. Available: http://journal.umuslim.ac.id/index.php/rkt/article/view/748

[22] R. Maddalena, K. Li, P. A. Chater, S. Michalik, and A. Hamilton, "Direct synthesis of a solid calcium-silicate-hydrate (C-S-H)," *Constr. Build. Mat .*, vol. 223, pp. 554–565, 2019, doi: 10.1016/j.conbuildmat.2019.06.024.

[23] S. M. Moayedian and M. Hejazi, "Stress-strain relationships for scaled gypsum mortar and cement mortar brick masonry," *J. Build. Eng* vol. 33, no. Aug t 2020, p. 101861, 2021, doi 10.1016/j.jobe.2020.101861.

[24] W. Wang, Y. Gan, and X. Kang, "Synthesis and characterization of sustainable eco-friendly unburned bricks from slate tailings," *J. Mater. Res Technol.*, vol. 14, pp. 1697–1708, 2021, doi: 10.1016/j.jmrt.2021.07.071.

[25] J. N. Sheth, "Future of brick and mortar retailing: how will it survive and thrive?," *J. Strateg. Mark.*, vol. 29, no. 7, pp. 598–607, 2021, doi: 10.1080/0965254X.2021.1891128.

[26] S. S. Park, Y. Y. Kim, B. J. Lee, and S. J. Kwon, "Evaluation of concrete durability performance with sodium silicate impregnants," *Adv. Mater. Sci. Eng.*, vol. 2014, 2014, doi: 10.1155/2014/945297.

[27] M. Ridwan, S. AM, B. Ulum, and F. Muhammad, "Pentingnya penerapan literature review pada penelitian ilmiah," *J. Masohi*, vol. 2, no. 1, pp. 42–51, 2021, doi: 10.36339/jmas.v2i1.427.

[28] Z. Xu *et al.*, "Magnetic and absorption properties in hundreds of megahertz band for a FeSi@SiO2 composite with brick stacking structure and crystallographic orientation," *J. Magnetism Magn. Mater.*, vol. 570, no. 1, p. 170491, 2023, doi: 10.1016/j.jmmm.2023.170491.

[29] S. Kahangi Shahreza, J. Niklewski, and M. Molnár, "Experimental investigation of water absorption and penetration in clay brick masonry under simulated uniform water spray exposure," *J. Build. Eng* vol. 43, no. Dec ber 2020, p. 102583, 2021, doi: 10.1016/j.jobe.2021.102583.

[30] Z. Lyu *et al.*, “Absorption characteristics and shrinkage mitigation of superabsorbent polymers in pavement concrete,” *Int. J. vement Eng.*, vol. 23, no. 2, pp. 270–284, 2022, doi: 10.1080/10298436.2020.1742334.

[31] P. B. Prajapati, N. Bagul, and G. Kalyankar, “Implementation of DoE and Risk-Based Enhanced Analytical Quality by Design Approach to Stability-Indicating RP-HPLC Method for Stability Study of Bosutinib,” *J. AOAC Int.*, vol. 104, no. 6, pp. 1742–1753, 2021, doi: 10.1093/jaoacint/qsab078.

[32] S. Panda, P. Sarkar, and R. Davis, “Effect of Water-Cement Ratio on Mix Design and Mechanical Strength of Copper Slag Aggregate Concrete,” *IOP Conf. Ser. Mater. Sci Eng.*, vol. 936, no. 1, pp. 1–8, 2020, doi: 10.1088/1757-899X/936/1/012019.