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Variations in Composition and Size of Red Sand in Pinang City, North Sumatra to Improve Concrete Quality

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Abstract*— This study further explores the problems in the concrete material studied in terms of variations in the structure of the constituent materials and the grain size of red sand on the compressive strength test of quality concrete material with code K-350. The primary raw material uses red sand with compositions ranging from 0%, 2%, 4%, and 6% with sizes ranging from 120, 100, and 80 mesh. After all the ingredients are mixed, printing is carried out according to the predetermined sample size; after the sample is deposited for one day and one night, the sample is opened from the mold mall. To see the quality of the sample, testing was carried out by testing the concrete structure through the SEM test, and the sample elements were looked at by testing XRD, compressive strength, and water absorption. The results obtained were a successive decrease in water absorption in red sand samples with a composition of 4%. In addition, the maximum compressive strength value was obtained at the proportion of 120 mesh material, and 6 percent of the material composition obtained a compressive strength value of 35.27 MPa. When viewed from the size of the concrete structure using the scanning Electron Microscope test, it was found that the size of the red sand mixture concrete structure has a much smaller pore structure when compared to other mixtures. and in the X-Ray Diffraction test, it was found to contain elements in the form of SiO2, CaO3, Ca (OH)2 with the highest intensity of silicon.

***Keywords*— Concrete material; composite; red sand; Pinang city sand**

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I. INTRODUCTION

Today's problem is the need for living facilities, especially for construction in settlements, buildings, bridges, highways, and others. Along with the increasing need for settlements, towers, bridges, and roads, the need for introductory materials in the form of concrete also increases. Along with the growing need for settlements, buildings, bridges, and roads, the need for introductory materials in the form of concrete also increases [1]. The latest information shows that the use of concrete globally reaches 8.8 billion tons/year, equivalent to 1.3 tons for one population on Earth. This figure is expected to continue to increase along with population growth and the development of science and technology [2]. Concrete, as one of the fundamental construction parts in buildings, makes this a strong reason, especially since concrete physically has good physical hardness and the constituent materials are relatively cheap and easy to obtain. [3].

Concrete can accept the pressure that is strong enough. Concrete-forming materials will have results that affect the concrete's physical strength sample to be used. The alternative sand is used to improve concrete's compressive strength and is an alternative in the form of red sand [4]. This material is obtained from a natural excavation process through excavations carried out by the community in the Padang Bulan area, which is in the Pinang City sub-district area in the province of North Sumatra[5], which is much finer and lighter than ordinary dug sand. This red sand is widely used to make roads in the area. The red sand of Labuhan Batu Selatan is used as a material for making concrete because it contains FeC, TaO ,SiO2, TaO2, and FeNi, as well as a significant quantity of readily available red sand silicon. [6].

The research results by [6] regarding the effect of compositional variations and red sand's size on concrete quality show that the mechanical properties of concrete with a maximum compressive strength of 5 percent and a grain size variation of 120 mesh can be acquired to boost the mechanical strength of concrete. The density of concrete is very good in this mixture. For testing, concrete's capacity to absorb water has decreased linearity.

The research results by [4], “the results of the full-strength test with a composition of 4% are in line with the decrease in the type of grain size; there is red sand with a grain size of 80 mesh, which is 32.3 MPa". According to the Indonesian National Standardization Agency, this has exceeded the pressure limit, but the results obtained have not found linearity. Experiments on K-225 concrete's quality have obtained compressive strength reaching K-400 [7].

Related to this background, this research tested concrete [8] with the K350 quality standard by utilizing red sand grains as a substitute for river sand [9]. Samples were prepared in 3 mixtures using composition variations [8], [10], [11] of 0 %, 2 %, 4 %, and 6 % with minor object variations of 80 mesh, 100 mesh, and 120 mesh, respectively [5], [9], [12].

II. Material And Methods

A. Preparation Ingredients and Proportions of the Mixture

The concrete mixture comes from a combination of its constituent composite materials [13]. The design results are influenced by the characteristics and properties of the material [14]. Planning is done to determine the composition, proportion, and materials to make concrete [15]. This is so that the mix ratio that can be used is SNI 03-2847-2002 [16], [17].

At this stage, materials are needed crushed stone, river sand, water, type I Portland cement, and red sand [18]. The object used as the test material is concrete with dimensions of 15 cm × 15 cm × 15 cm. Each test material was varied by adding red sand with variations[19] of 0%, 2%, 4%, and 6%. In this research, K-350 quality concrete was manufactured [20]–[22]. The composition of the concrete mix is 1 Portland cement: 1.5 sand: 2.2 crushed stone with a water-cement factor (FAS) of 0.5. In total, the composition of the concrete ingredients for each mixture [23]–[25] is shown in Table 1.

TABLE I
MIXED PROPORTIONS

Materials	**Mixed (80; 100; 120) Mesh (1.77; 1.49; 1.25) x 10^{-4} m**			
	0%	2%	4%	6%
Cement (kg)	5.61	5.61	5.61	5.61
River Sand (kg)	8.4	8.23	8.06	7.9
Gravel (kg)	12.4	12.4	12.4	12.4
Red Sand (kg)	0	0.17	0.24	0.5
FAS (kg)	2.8	2.8	2.8	2.8

B. Methods

1) Preparation of test objects: In this research, 4 (four) concrete mixtures were made consisting of 3 (three) red sand concrete mixtures and 1 () regular concrete (without mixture). In ordinary concrete [26], 100% river sand is used [27]. At this stage, the ingredients are mixed manually using a shovel.

2) Maintenance: At this stage, the treatment is carried out by putting the sample into the soaking tub and then burying it for 28 days in the soaking tub. After soaking the test material, it is drained from the bath to reduce its water content, and this drying process takes 24 hours. After that, the test raw material can be used for testing at a later stage.

3) Testing: The first test step is testing water absorption, where in this test, it is necessary to see directly how the absorption level occurs in the air cavities in the material [28]. So that from the observation process carried out it can be calculated mathematically, the amount of water absorption that occurs in this study [29] can be seen in the equation below:

$$Water\ absorption\ (\%) = \frac{mb-mk}{mk} x100 \qquad (1)$$

where mb is a wet mass of the test object (kg), and mk is the dry mass of the specimen (kg).

4) Compressive Strength: The compressive strength test measures the compressive strength of the test material currently used, concrete, so the size of the compressive test can be known. In Indonesia, the standard reference is the Indonesian National Standard [16] (SNI) 03-2847-2002. The test equipment used is a Compression Testing Machine (CTM) [30].

Mathematically, the magnitude of the pressure of a material is:

$$P = \frac{F}{A} \qquad (2)$$

where F is compressive strength (MPa), P is the maximum load (N), and A is the cross-sectional area of the test object (m^2).

5) XRD: The X-ray diffraction test is a tool used to identify the phase structure from the crystal appearance of the test material during testing. XRD also functions to see the phase composition [31].

6) SEM (Scanning Electron Microscope): The data to be obtained is an analysis of the surface or layer. The resulting image is topography in the form of protrusions, indentations, and holes on the surface [32].

III. Results And Discussions

A. Water Absorption

From the existing data, it can be seen clearly that the results of testing the water absorption [33] capacity of each mixture obtained results with different variations [34], [35] when compared to sizes 80, 100, and 120 Mesh and the percentage of materials varied on red sand and river sand as the main ingredients used. So, we can see the projection results of the research data in the graph of Figure 1.

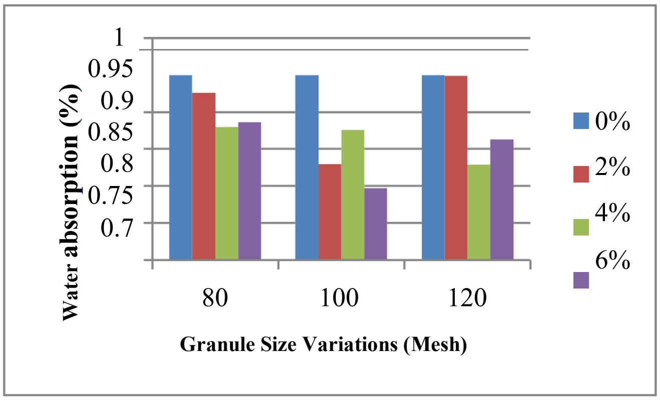


Fig. 1 Relationship of water absorption to variations in composition and grain size of red sand overall.

From Figure 1, it can be seen that a decrease in water absorption [36] Is seen in the composition of 80 meshes with a variation in the composition [37] of the grains of 0%, 2%, and 4% occurring successively and an increase in the composition of 6%. The minimum water absorption [38], [39] value occurs at a composition of 6% at a grain size of 100 mesh [40]. The addition of red sand can reduce the maximum water absorption by 16%.

B. Compressive Strength

Result Testing strong press down to every mixture. Get results in picture 2. In Figure 2, it can be seen that the increase in compressive strength occurred in concrete [41], [42]with a grain size variation of 120 mesh with successive increases of 29.78 MPa, 33.24 MPa, 33.77 MPa, and 35.37 MPa. The addition of red sand can increase the maximum compressive strength [43], [44] by 20% of the K-350 concrete quality standard [45].

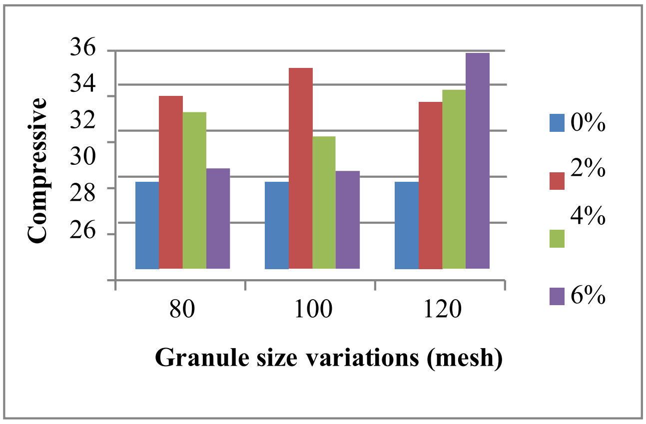


Fig. 2 The relationship of compressive strength to variations in the composition and size of the red sand grains.

C. XRD (X-Ray Diffraction)

The results of the XRD test showed diffraction patterns in concrete with variations of 120 mesh red sand grains and composition variations of 0%, 2%, 4%, and 6%, with the highest peaks occurring in the SiO2 element. The diffraction pattern is shown in Figure 3.

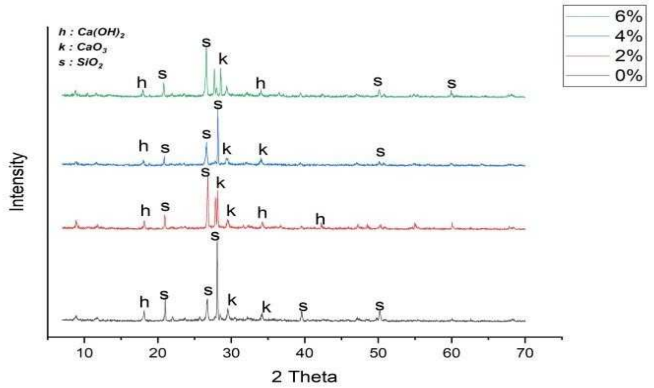
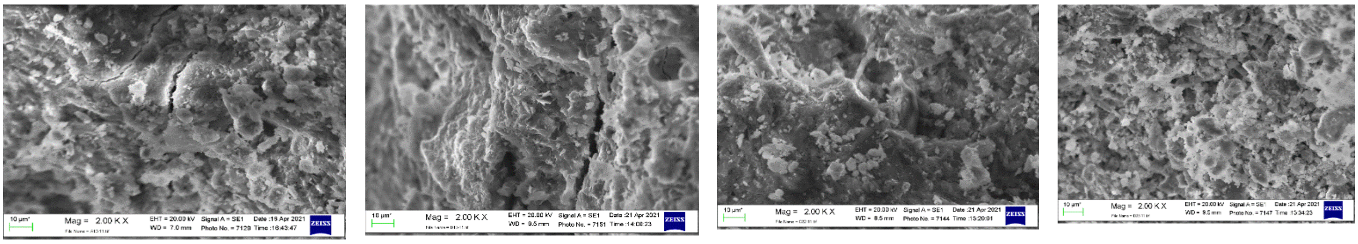


Fig. 3 Red sand mix concrete sample diffraction pattern size 120 mesh (a) 0%, (b) 2%, (c) 4% and (d) 6%.

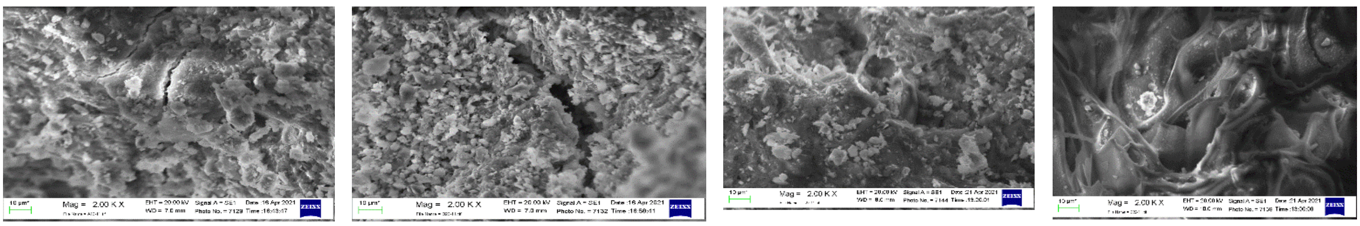
D. SEM

The (Scanning Electron Microscope) SEM test was carried out to determine the concrete's morphology. From the following 2000x magnification, you can see the test results on the concrete sample[46]. SEM, data regarding the pore size in concrete can also be obtained. SEM test results are shown in Figures 4 and 5.



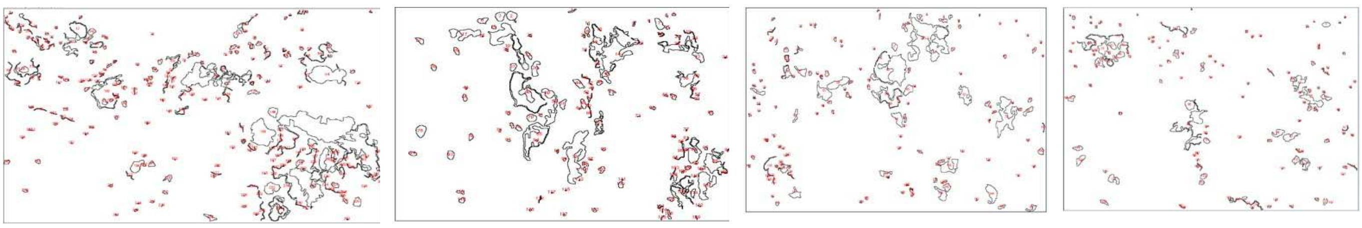
(a) (b) (c) (d)

Fig. 4 SEM results on red sand mix concrete samples size 120 mesh composition (a) 0%, (b) 2%, (c) 4% and (d) 6% with magnification 2000x.



(a) (b) (c) (d)

Fig. 5 SEM results on red sand mix concrete samples composition 4% size (a) without mixture, (b) 80 mesh, (c) 100 mesh, and (d) 120 mesh with magnification 2000x



(a) (b) (c) (d)

Fig. 6 The results of SEM analysis on a sample of red sand mixed concrete size 120 mesh composition (a) 0%, (b) 2%, (c) 4% and (d) 6% magnification 2000x.

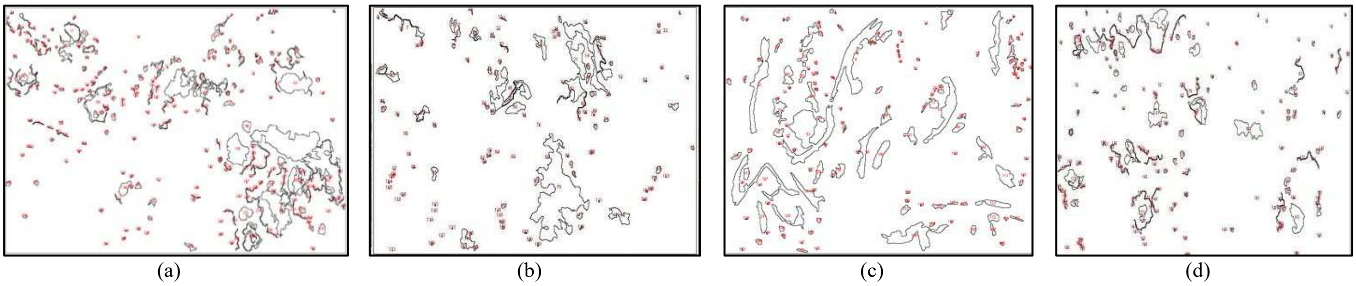


Fig. 7 The results of SEM analysis on red sand mix concrete samples composition 4% size (a) without mixture, (b) 80 mesh, (c) 100 mesh and (d) 120 mesh with 2000x magnification

The results of the water absorption and compressive strength tests of concrete with the addition of variations in grain size and variations in the composition of red sand that have been worked and treated for 28 days and dried for 24 hours can be seen in Figure 1. It shows that concrete without a red sand mixture has a high-water absorption capacity. Based on research conducted by [4], "the more pores the concrete has, the higher its absorption power so that its resistance will decrease". Cavities (pores) in concrete [47] are caused by inaccurate quality and composition of the constituent materials. Concrete additives play an essential role in the concrete [48] manufacturing process because they can modify and adapt the properties of concrete [46] to suit the needs and Decreased absorption.

This decrease in water absorption can be affected by the addition of materials because the cavities contained in the materials that make up the composition of the concrete [26] material can be compacted by adding red sand so that the red sand particles can enter the empty pores to increase the density of the concrete material [49]. The results of the SEM test reveal the concrete's density, as shown in Figures 4 and 5. Visible pores indicate the density of the concrete [50]with black color and holes [51]. This indicates that the addition of red sand composition with a specific size effectively reduces water absorption so that the greater the water absorption capacity the lower the compressive strength value obtained. The specimen's pressure test is carried out when the concrete is 28 days old since immersion. The substantial pressure value is influenced by the composition of the materials used for its formation and the bond between the cement paste and the cement. The compressive strength of concrete is determined by setting the ratio of cement, fine aggregate, and water [5].

The composition variation of (0, 5, 10, 15, 20) % experienced the highest increase in composition variation of 5% and began to decrease by 10%. When the composition is varied to (0, 2, 4, 6)% with the lowest percentage increase in the pressure force value of 1.6% on the variation of the red sand mixed with a size of 100 mesh and a composition variation of 6% and the highest percentage increase in pressure strength of 18.7% on the variation of the red sand mixed with a size of 120 mesh and the composition variation of 6%. This happens because the addition of sand of a small size can reduce the number of pores and increase the strength of pressure. The composition selection was also chosen below 10% because it was based on research [52] with a composition variation of 0.5%: 5%, 2%: 15%, 4%: 25% obtained the highest pressure strength value with the composition of the mixture with the addition of fine aggregates as much as 5% [53], [54].

The pressure force drop factor can also be influenced by the gradation of the size of the homogeneous sand granules. If the size is uniform, there is a lot of free space or gaps between the units. Therefore, a suitable aggregate for concrete is a granular aggregate that changes when the free space between particles is filled with small particles [55].

Due to the smaller size of red sand grains, adding red sand effectively raises the level of SiO 2 in concrete[56]. Because SiO2 is one of the most common compositions found in red sand and Portland cement, using this element will make it simpler to produce a mixture of stronger concrete. Figure 3 can also be used to conclude that SiO2 [57], [58] has the most dispersed intensity of all the elements in concrete [59], [60].

The analysis carried out on 0% mixed concrete (a) in Figure 5 shows a more evenly distributed pore distribution with larger pore size. Meanwhile, in Figure 5 (b), it can be seen that the gradation of the aggregate is not good, causing the material to bind less, thereby affecting the density of the concrete. In figures (c) and (d), it can be seen that the spread of pore pores is almost evenly arranged, causing the pore size in concrete to shrink and improve the quality of concrete[61]. The aggregate granules' size also affects the pores' arrangement and size. Fine granules can fill the free space in concrete, make the concrete composition denser, and create low water absorption. The comparison of Figure 5 shows that the addition of 6% red sand has the best morphology compared to concrete without a mixture of red sand (standard).

In aggregate samples, using below average sizes can be used as an alternative to increasing the strength of the concrete samples used so that the compressive strength can improve and reach the standards set by the government—the raw quality of the sample material is to have maximum quality. In addition, if the concrete sample aggregate has finer grain particles with different size and shape variations, this will affect the density of the concrete, and the finer particles will fill the empty cavities in the concrete sample. So that the quality of the concrete is much denser and more robust and the quality can be optimal [62].

IV. Conclusion

From the results of the research that has been carried out, there are several findings, namely, in the lowest water absorption test at a composition of 4%; however, this is not in line with the findings in research, namely in the compressive strength test there is a significant increase in variations in size composition material of 120 mesh. This indicates that homogeneous mixing during casting has not occurred. From the compressive strength testing process with variations from various samples with the composition and size of the red sand particles, a new fact was obtained that the red sand aggregate mixture could increase the strength of concrete. The amount of strength obtained from the optimal compressive strength test was obtained in the test sample, namely at 120 mesh size with a mixed composition of 6%. From the data above, we can analyze that the size of the aggregate [63] particles affects the sample's compressive strength, with the small size of the aggregate grains being able to fill the empty pore space of the concrete sample being tested. This has implications for the resulting concrete structure to become denser and the bonding of the particles to become stronger so that the test value of the compressive strength obtained is K-450 from K-350, where there is a significant increase. Based on the XRD test, it was found that the elements contained were Ca (OH)2, SiO2 and CaO3, with the highest intensity being SiO2 compared to other concrete components. One of the components that red sand cement contains to improve concrete's compressive strength is SiO2. All crystal structures formed are hexagonal. Based on these conclusions, the authors provide two suggestions. Namely, it is necessary to pay attention to further research when the concrete casting process is carried out even better to obtain homogeneity[64] of the mixture to fill the pore voids and increase the compressive strength of the concrete. Further research in concrete treatment so that the test object is not crushed is also necessary.

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REFERENCES

[1] A. Dummer, S. Smaniotto, and G. Hofstetter, "Experimental and numerical study on nonlinear basic and drying creep of normal strength concrete under uniaxial compression," *Constr. Build. Mater.*, vol. 362, pp. 1–9, 2023, doi: 10.1016/j.conbuildmat.2022.129726.

[2] A. M. Moasas *et al.*, "A worldwide development in the accumulation of waste tires and its utilization in concrete as a sustainable construction material: A review," *Case Stud. Constr. Mater.*, vol. 17, p. e01677, 2022, doi:10.1016/j.cscm.2022.e01677.

[3] S. M. Al-Tarbi, O. S. Baghabra Al-Amoudi, M. A. Al-Osta, W. A. Al-Awsh, M. R. Ali, and M. Maslehuddin, "Development of eco-friendly hollow concrete blocks in the field using wasted high-density polyethylene, low-density polyethylene, and crumb tire rubber," *J. Mater. Res. Technol.*, vol. 21, pp. 1915–1932, 2022, doi:10.1016/j.jmrt.2022.10.027.

[4] M. H. Harahap and A. E. Putri, "Effect of variations in the composition and size of red sand grains on the quality of K-225 concrete," *J. Met. Mater. Miner.*, vol. 30, no. 4, 2020, doi: 10.14456/jmmm.2020.54.

[5] I. Irfandi *et al.*, "E-learning and Physics Teaching Materials Based on Malay Ethnoscience on the East Coast," *J. Pendidik. IPA Indones.*, vol. 12, no. 3, pp. 366–376, 2023. doi: 10.15294/jpii.v12i3.

[6] M. Harahap, H. Br S Milala, I. Irfandi, and W. Ritonga, "Effect of Composition Variation and Size of Red Sand Grain to Concrete Quality," 2019. doi: 10.4108/eai.18-10-2018.2287370.

[7] B. Qi, S. Gao, and P. Xu, "The application of rubber aggregate-combined permeable concrete mixture in sponge city construction," *Coatings*, vol. 13, no. 1, p. 87, 2023. doi:10.3390/coatings13010087.

[8] Y. Liu, P. Ren, N. Garcia-Troncoso, K. H. Mo, and T.-C. Ling, "Roles of enhanced ITZ in improving the mechanical properties of concrete prepared with different types of recycled aggregates," *J. Build. Eng.*, vol. 60, p. 105197, 2022, doi: 10.1016/j.jobe.2022.105197.

[9] M. H. Harahap, W. Ritonga, I. Irfandi, and M. Zubir, "Optimization of Red Sand Particle Size and Composition in Mixture with Ordinary Sand to Enhance Concrete Quality," *Civ. Environ. Eng.*, vol. 18, no. 2, pp. 424–429, 2022, doi: doi:10.2478/cee-2022-0039.

[10] A. Q. Ahdal *et al.*, "Mechanical performance and feasibility analysis of green concrete prepared with local natural zeolite and waste PET plastic fibers as cement replacements," *Case Stud. Constr. Mater.*, vol. 17, p. e01256, 2022, doi: doi.org/10.1016/j.cscm.2022.e01256.

[11] D. Rachmadena, M. Faizal, and M. Said, "Conversion of polypropylene plastic waste into liquid fuel with catalytic cracking process using Al2O3 as catalyst," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 8, no. 3, pp. 694–700, 2018, doi: 10.18517/ijaseit.8.3.2586.

[12] J. Zhang *et al.*, "Impact resistance of concrete pavement surface reinforced with fibre mesh," *Int. J. Pavement Eng.*, vol. 24, no. 1, p. 2088753, 2023. doi:10.1080/10298436.2022.2088753.

[13] D. Li, Y. Tang, X. Zuo, X. Zhao, X. Zhang, and H. Yang, "Preparation of hierarchical porous microspheres composite phase change material for thermal energy storage concrete in buildings," *Appl. Clay Sci.*, vol. 232, p. 106771, 2023, doi: 10.1016/j.clay.2022.106771.

[14] K. Lazaar, W. Hajjaji, B. Moussi, F. Rocha, J. Labrincha, and F. Jamoussi, "Metakaolin and demolition wastes in eco-based sand consolidated concrete," *Boletín la Soc. Española Cerámica y Vidr.*, vol. 60, no. 4, pp. 229–242, 2021, doi:10.1016/j.bsecv.2020.02.004.

[15] R. Ali, M. Muayad, A. S. Mohammed, and P. G. Asteris, "Analysis and prediction of the effect of Nanosilica on the compressive strength of concrete with different mix proportions and specimen sizes using various numerical approaches," *Struct. Concr.*, vol. 24, no. 3, pp. 4161–4184, 2023. doi: 10.1002/suco.202200718.

[16] M. Lutfie and A. W. Latuba, "Review of K-250 Concrete Compressive Strength Using Mix Design Manual on Development Projects Continued Talud Airport of Syukuran Aminuddin Amir Luwuk," in *4th Borobudur International Symposium on Science and Technology 2022 (BIS-STE 2022)*, 2023, pp. 252–261. doi:10.2991/978-94-6463-284-2_30.

[17] W. O. Nugroho, A. Sagara, and I. Imran, "The evolution of Indonesian seismic and concrete building codes: From the past to the present," *Structures*, vol. 41, pp. 1092–1108, 2022, doi:10.1016/j.istruc.2022.05.032.

[18] D. Y. Permata, B. S. Sagabio, and K. N. S. Ayuningtyas, "Performance of Resilient Modulus (SMix) and Dynamic Modulus ((|E*|) on Asphalt Concrete – Wearing Course (AC-WC) Using Pen 60/70 Asphalt and Styrene-Butadiene-Styrene (SBS) Polymer," *Int. J. Adv. Sci. Eng. Inf. Technol.*, vol. 12, no. 2, pp. 655–660, 2022, doi:10.18517/ijaseit.12.2.13719.

[19] G. L. Vieira, J. Z. Schiavon, P. M. Borges, S. R. da Silva, and J. J. de Oliveira Andrade, "Influence of recycled aggregate replacement and fly ash content in performance of pervious concrete mixtures," *J. Clean. Prod.*, vol. 271, p. 122665, 2020. doi:10.1016/j.jclepro.2020.122665.

[20] P. Mushar and others, "The Strength of Reinforced Concrete Slabs of 30% Candlenut Shell Variation Using Destructive Testing Methods," in *IOP Conference Series: Earth and Environmental Science*, 2022, vol. 1117, no. 1, p. 12030. doi: 10.1088/1755-1315/1117/1/012030.

[21] R. J. M. Wolfs, F. P. Bos, and T. A. M. Salet, "Triaxial compression testing on early age concrete for numerical analysis of 3D concrete printing," *Cem. Concr. Compos.*, vol. 104, p. 103344, 2019, doi: 10.1016/j.cemconcomp.2019.103344.

[22] S. Laivando, O. Setyandito, C. Pranata, C. Purnamasari, M. Y. Syahputra, and V. Kosalim, "Analysis of comparison internal forces of girder consists of shear forces and bending moment on bridge structure at port in Subang Regency West Java," in *AIP Conference Proceedings*, 2023, vol. 2846, no. 1. doi: 10.1063/5.0155430.

[23] O. Youssf *et al.*, "Mechanical performance and durability of geopolymer lightweight rubber concrete," *J. Build. Eng.*, vol. 45, p. 103608, 2022. doi: 10.1016/j.jobe.2021.103608.

[24] O. A. Mayhoub, E.-S. A. R. Nasr, Y. A. Ali, and M. Kohail, "The influence of ingredients on the properties of reactive powder concrete: A review," *Ain Shams Eng. J.*, vol. 12, no. 1, pp. 145–158, 2021. doi:10.1016/j.asej.2020.07.016.

[25] C. Zhang *et al.*, "Mix design concepts for 3D printable concrete: A review," *Cem. Concr. Compos.*, vol. 122, p. 104155, 2021. doi: 10.1016/j.cemconcomp.2021.104155.

[26] S. C. Moghaddam, R. Madandoust, M. Jamshidi, and I. M. Nikbin, "Mechanical properties of fly ash-based geopolymer concrete with crumb rubber and steel fiber under ambient and sulfuric acid conditions," *Constr. Build. Mater.*, vol. 281, p. 122571, 2021. doi:10.1016/j.conbuildmat.2021.122571.

[27] B. Arulmoly and C. Konthesingha, "Pertinence of alternative fine aggregates for concrete and mortar: A brief review on river sand substitutions," *Aust. J. Civ. Eng.*, vol. 20, no. 2, pp. 272–307, 2022. doi:10.1080/14488353.2021.1971596.

[28] M. Sambucci, A. Sibai, L. Fattore, R. Martufi, S. Lucibello, and M. Valente, "Finite element multi-physics analysis and experimental testing for hollow brick solutions with lightweight and eco-sustainable cement mix," *J. Compos. Sci.*, vol. 6, no. 4, p. 107, 2022. doi:10.3390/jcs6040107.

[29] S. Sander, G. Meschut, U. Kroll, and A. Matzenmiller, "Methodology for the systematic investigation of the hygrothermal-mechanical behavior of a structural epoxy adhesive," *Int. J. Adhes. Adhes.*, vol. 113, p. 103072, 2022, doi: 10.1016/j.ijadhadh.2021.103072.

[30] A. Talaat, A. Emad, A. Tarek, M. Masbouba, A. Essam, and M. Kohail, "Factors affecting the results of concrete compression testing: A review," *Ain Shams Eng. J.*, vol. 12, no. 1, pp. 205–221, 2021. doi:10.1016/j.asej.2020.07.015.

[31] M. Ren, X. Wen, X. Gao, and Y. Liu, "Thermal and mechanical properties of ultra-high performance concrete incorporated with microencapsulated phase change material," *Constr. Build. Mater.*, vol. 273, p. 121714, 2021. doi:10.1016/j.conbuildmat.2020.121714.

[32] J. Yu *et al.*, "Mechanically sensing and tailoring electronic properties in two-dimensional atomic membranes," *Curr. Opin. Solid State Mater. Sci.*, vol. 25, no. 2, p. 100900, 2021, doi:10.1016/j.cossms.2021.100900.

[33] L. Yang, G. Liu, D. Gao, and C. Zhang, "Experimental study on water absorption of unsaturated concrete: w/c ratio, coarse aggregate and saturation degree," *Constr. Build. Mater.*, vol. 272, p. 121945, 2021. doi:10.1016/j.conbuildmat.2020.121945

[34] J. Huang, Y. Zhang, Y. Sun, J. Ren, Z. Zhao, and J. Zhang, "Evaluation of pore size distribution and permeability reduction behavior in pervious concrete," *Constr. Build. Mater.*, vol. 290, p. 123228, 2021. doi:10.1016/j.conbuildmat.2021.123228

[35] A. M. Saba *et al.*, "Strength and flexural behavior of steel fiber and silica fume incorporated self-compacting concrete," *J. Mater. Res. Technol.*, vol. 12, pp. 1380–1390, 2021. doi:10.1016/j.jmrt.2021.03.066

[36] G. L. Golewski, "Assessing of water absorption on concrete composites containing fly ash up to 30% in regards to structures completely immersed in water," *Case Stud. Constr. Mater.*, vol. 19, p. e02337, 2023. doi:10.1016/j.cscm.2023.e02337.

[37] S. Zhuang, Q. Wang, and M. Zhang, "Water absorption behaviour of concrete: novel experimental findings and model characterization," *J. Build. Eng.*, vol. 53, p. 104602, 2022. doi:10.1016/j.jobe.2022.104602.

[38] M. E. Sosa, Y. A. V. Zaccardi, and C. J. Zega, "A critical review of the resulting effective water-to-cement ratio of fine recycled aggregate concrete," *Constr. Build. Mater.*, vol. 313, p. 125536, 2021. doi:10.1016/j.conbuildmat.2021.125536.

[39] Y. Tan, X. Lu, R. He, H. Chen, and Z. Wang, "Influence of superabsorbent polymers (SAPs) type and particle size on the performance of surrounding cement-based materials," *Constr. Build. Mater.*, vol. 270, p. 121442, 2021. doi:10.1016/j.conbuildmat.2020.121442.

[40] D. Vafaei, R. Hassanli, X. Ma, J. Duan, and Y. Zhuge, "Sorptivity and mechanical properties of fiber-reinforced concrete made with seawater and dredged sea-sand," *Constr. Build. Mater.*, vol. 270, p. 121436, 2021. doi:10.1002/suco.202000211.

[41] F. Moccia, Q. Yu, M. Fernández Ruiz, and A. Muttoni, "Concrete compressive strength: From material characterization to a structural value," *Struct. Concr.*, vol. 22, pp. E634--E654, 2021. doi:10.1016/j.conbuildmat.2021.123550.

[42] H. Cheng, T. Liu, D. Zou, and A. Zhou, "Compressive strength assessment of sulfate-attacked concrete by using sulfate ions distributions," *Constr. Build. Mater.*, vol. 293, p. 123550, 2021. doi:10.1016/j.conbuildmat.2021.123550.

[43] B. A. Tayeh, M. H. Akeed, S. Qaidi, and B. H. A. Bakar, "Influence of sand grain size distribution and supplementary cementitious materials on the compressive strength of ultrahigh-performance concrete," *Case Stud. Constr. Mater.*, vol. 17, p. e01495, 2022.

[44] M. Xu, L. Liu, Y. Deng, A. Zhou, S. Gu, and J. Ding, "Influence of sand incorporation on unconfined compression strength of cement-based stabilized soft clay," *Soils Found.*, vol. 61, no. 4, pp. 1132–1141, 2021.

[45] M. H. Harahap, W. Ritonga, and N. Adelia, "Characteristics of Concrete With Red Sand Mixture 80 Mesh Grain Size After Combustion," *J. Penelit. Pendidik. IPA*, vol. 9, no. 8, pp. 6540–6547, 2023. doi:10.29303/jppipa.v9i8.3107.

[46] M. Amin, A. M. Zeyad, B. A. Tayeh, and I. S. Agwa, "Effects of nano cotton stalk and palm leaf ashes on ultrahigh-performance concrete properties incorporating recycled concrete aggregates," *Constr. Build. Mater.*, vol. 302, p. 124196, 2021. doi:10.1016/j.conbuildmat.2021.124196.

[47] T. Salgueiro, A. Samagaio, M. Gonçalves, A. Figueiredo, J. Labrincha, and L. Silva, "Incorporation of phase change materials in an expanded clay containing mortar for indoor thermal regulation of buildings," *J. Energy Storage*, vol. 36, p. 102385, 2021. doi:10.1016/j.est.2021.102385.

[48] W. Kujawa, E. Olewnik-Kruszkowska, and J. Nowaczyk, "Concrete strengthening by introducing polymer-based additives into the cement matrix—A mini review," *Materials (Basel).*, vol. 14, no. 20, p. 6071, 2021. doi:10.3390/ma14206071.

[49] J. Ahmad *et al.*, "Concrete Made with Dune Sand: Overview of Fresh, Mechanical and Durability Properties," *Materials (Basel).*, vol. 15, no. 17, pp. 1–19, 2022, doi: 10.3390/ma15176152.

[50] T. He, T. Wang, D. Xie, and J. J. K. Daemen, "The mechanism of pores enhancing the deformation of completion cement under confining pressure," *Cem. Concr. Compos.*, vol. 125, p. 104322, 2022. doi:10.1016/j.cemconcomp.2021.104322.

[51] Y. Wang, J. Liu, B. Dong, J. Ren, and G. Fang, "Stabilization/solidification of sand-washing slurry used for porous cold-bonded ceramsite," *Cem. Concr. Compos.*, vol. 134, p. 104771, 2022. doi:10.1016/j.cemconcomp.2022.104771.

[52] D. dan M. Sirait, "Pengaruh Komposisi Serat Ijuk dan Batu Gamping Terhadap Sifat Mekanik Beton," *J. EINSTEIN*, vol. 7, no. 1, pp. 72–82, 2018.

[53] A. Gholampour, J. Zheng, and T. Ozbakkaloglu, "Development of waste-based concretes containing foundry sand, recycled fine aggregate, ground granulated blast furnace slag and fly ash," *Constr. Build. Mater.*, vol. 267, p. 121004, 2021. doi:10.1016/j.conbuildmat.2020.121004.

[54] B. Li, S. Hou, Z. Duan, L. Li, and W. Guo, "Rheological behavior and compressive strength of concrete made with recycled fine aggregate of different size range," *Constr. Build. Mater.*, vol. 268, p. 121172, 2021. doi:10.1016/j.conbuildmat.2020.121172.

[55] B. Ali, M. H. El Ouni, and R. Kurda, "Life cycle assessment (LCA) of precast concrete blocks utilizing ground granulated blast furnace slag," *Environ. Sci. Pollut. Res.*, vol. 29, no. 55, pp. 83580–83595, 2022, doi:10.1007/s11356-022-21570-7.

[56] C. B. Nayak, P. P. Taware, U. T. Jagadale, N. A. Jadhav, and S. G. Morkhade, "Effect of SiO2 and ZnO nano-composites on mechanical and chemical properties of modified concrete," *Iran. J. Sci. Technol. Trans. Civ. Eng.*, vol. 46, no. 2, pp. 1237–1247, 2022. doi:10.1007/s40996-021-00694-9.

[57] Z. Wu, K. H. Khayat, C. Shi, B. F. Tutikian, and Q. Chen, "Mechanisms underlying the strength enhancement of UHPC modified with nano-SiO2 and nano-CaCO3," *Cem. Concr. Compos.*, vol. 119, p. 103992, 2021. doi:10.1016/j.cemconcomp.2021.103992.

[58] Y. Xu, J. Wang, P. Zhang, J. Guo, and S. Hu, "Enhanced effect and mechanism of colloidal nano-SiO2 modified rubber concrete," *Constr. Build. Mater.*, vol. 378, p. 131203, 2023. doi:10.1016/j.conbuildmat.2023.131203.

[59] H. Long, L. Chen, B. Dong, Y. Sun, Y. Yan, and C. Chen, "The electronic properties and surface chemistry of passive film on reinforcement: Effect of composition of simulated concrete pore solution," *Constr. Build. Mater.*, vol. 360, p. 129567, 2022. doi:10.1016/j.conbuildmat.2022.129567.

[60] M. Zhang, D. Ma, J. Cui, K. Liu, S. Sun, and J. Li, "Scouring erosion resistance of nano-marine concrete under the coupled effect of chloride attack and dry-wet cycles," *Constr. Build. Mater.*, vol. 411, p. 134227, 2024. https://doi.org/10.1016/j.conbuildmat.2023.134227

[61] O. Y. Bayraktar, G. Kaplan, O. Gencel, A. Benli, and M. Sutcu, "Physico-mechanical, durability and thermal properties of basalt fiber reinforced foamed concrete containing waste marble powder and slag," *Constr. Build. Mater.*, vol. 288, p. 123128, 2021. doi:10.1016/j.conbuildmat.2021.123128.

[62] Y. X. Chen, K. M. Klima, H. J. H. Brouwers, and Q. Yu, "Effect of silica aerogel on thermal insulation and acoustic absorption of geopolymer foam composites: The role of aerogel particle size," *Compos. Part B Eng.*, vol. 242, p. 110048, 2022, doi:10.1016/j.compositesb.2022.110048.

[63] S. M. A. Qaidi *et al.*, "Ultra-high-performance geopolymer concrete: A review," *Constr. Build. Mater.*, vol. 346, p. 128495, 2022. doi:10.1016/j.conbuildmat.2022.128495.

[64] P. Mehrabi *et al.*, "Effect of pumice powder and nano-clay on the strength and permeability of fiber-reinforced pervious concrete incorporating recycled concrete aggregate," *Constr. Build. Mater.*, vol. 287, p. 122652, 2021. doi:10.1016/j.conbuildmat.2021.122652.