http://journal.rmutp.ac.th/

Effect of Stone Dust on the Properties of Interlocking Block

Chookiat Choosakul[1] Tawich Klathae[1] Suporn Rittipuakdee[1] Khwanchiwa Yongsata[2] Sunun Monkaew[3]* and Saravut Jaritngam[4]

[1]College of Industrial Technology and Management, Rajamangala University of Technology Srivijaya
[2]Faculty of Engineering and Technology, Rajamangala University of Technology Srivijaya
[3]Faculty of Engineering, Rajamanagala University of Technology Phra Nakhon
[4]Faculty of Engineering, Prince of Songkhla University
[1]99 Moo 4, Tambol Tongnien, Khanom, Nokhon Si Thammarat 80210
[2]179 Moo 3, Tambol Maifad, Sikao, Trang 92150
[3]1381 Pibul Songkhram Road, Bangsue, Bangkok 10800
[4]15 Karnjanavanich Road, Hat Yai, Songkhla 90110

Received 27 February 2023; Revised 1 November 2023; Accepted 30 November 2023

Abstract

This research aimed to study the properties of interlocking block mixed with stone dust in the ratio of 0, 10, 20 and 30 by weight of cement. The ratio of cement to lateritic soil was 1: 6 by weight. The optimum moisture content (OMC) was obtained from the Standard Proctor Test. Square interlocking block formwork of round-flowered type with holes, size 12.5 x 10 x 25 centimeters, was formed by a manual compression molding machine. Conduct tests for the compressive strength, density, and water absorption of interlocking block mixed with stone dust in compliance with the Thai community product standard of interlocking block (TCPS 602-2004). The results of the study found that the use of stone dust of cement in the production of interlocking block resulting in increased the water absorption and density, but the compressive strength were decreased. All mixing ratios of interlocking block have the measured properties in accordance with the TCPS 602-2004 for non-load bearing type. The percentage of displacement of stone dust suitable for the production of interlocking block this time is 30% with compressive strength of 4.36 MPa, density of 1,707 kilograms per cubic meter and absorption of water 253 kilograms per cubic meter, respectively, at a curing life of 28 days.

Keywords : Interlocking Block; Lateritic Soil; Stone Dust

***** Corresponding Author. Tel.: +668 9213 9943, E-mail Address: Sunun.m@rmutp.ac.th***

1. Introduction

Interlocking block is a brick that has been developed to be strong, convenient and quick to use in construction. It also has a beautiful form. Moreover, the form with holes, grooves and tenons make it can be cemented both horizontal and vertical without mortar blocks one by one. It can be stacked and then, a mortar can be filled into the groove, with compaction. That is an easy way to lay brick, resulting in a quick construction and a strong stability of the building [1]. Interlocking block have many advantages: such as reductions in cost and construction time, attractive form and ingredients that can be found locally. It also reduces the use of high technology and imported materials. Buildings constructed with interlocking block are classified as non-permanent buildings, which cannot be built more than 2 floors according to the Building Regulations, Bangkok Metropolitan Administration [2].

Interlocking block require Portland cement as the main mixture. The excessive utilization and rising cost of limestone, the essential component in cement production, could result in the likelihood of future shortages and elevated cement prices. The Portland cement production process requires up to 1,400°C, and to produce 1 ton of Portland cement, 0.96 tons of carbon dioxide (CO_2) is generated into the atmosphere [3]. The cement industry also emits sulfur oxides (SO_3) and nitrogen oxides (NO_x), which are part of the greenhouse effect and acid rain [4]. If you look at global production, it accounts for 8% of total greenhouse gas emissions per year [5]. In Thailand, the average cement production is 30.57 million tons per year (2017-2020) [6]. Therefore, it is necessary to explore substituting or reducing the quantity of Portland cement with other materials. It can help reduce the amount of CO_2 production, which contributes to the greenhouse effect.

In the past research, there are other materials that have been used to replace cement in the production of interlocking block such as bagasse ash, chaff and diatomaceous earth [7], biomass ash [8] and crushed oyster shells [9]. In addition, the result of [10] shows that the chemical composition of stone dust as shown in **Table 1** contained the amount of SiO_2, Al_2O_3 and Fe_2O_3 at 36.07, 19.86 and 13.67 respectively. Sum of SiO_2, Al_2O_3 and Fe_2O_3 was 70% which had LOI less than a 10% including SO_3 less than a 4%. Considering the chemical composition of decomposed stone dust, the chemical composition of stone dust can be classified as pozzolanic material Class N, according to the standard of ASTM C 618 [11]. According to the study of Imrose et al. [12]. It was found that replacing cement with 3% stone dust resulted in an increase in compressive strength of 22.76% and an increase in tensile strength of 13.47%.

Table 1 The chemical composition of Portland cement type 1 and stone dust [10]

Chemical Composition (%)	OPC	Stone dust
SiO_2	20.62	36.07
Al_2O_3	5.22	19.86
Fe_2O_3	3.10	13.67
SO_3	2.70	3.29
MgO	0.91	2.47
Na_2O	0.07	1.31
K_2O	0.50	2.12
CaO	64.99	16.78
P_2O_5	-	0.21
LOI	1.13	5.80

From the data on the amount of stone wells in Nakhon Si Thammarat and Surat Thani provinces, there are many sources [13]. Consequently, the study of the possible use of stone dust to replacement of Portland cement type 1 would reduce the amount of cement in an appropriate proportion to produce of interlocking block in order to use natural waste materials as mixture to make benefits and increase the value.

2. Research Methodology

2.1 Research Materials

This research uses Ordinary Portland Cement (OPC) qualified according to TIS 15-2004 [14], with the specific gravity of equal to 3.13 and stone dust (SD) from a stone well in Khanom District, Nakhon Si Thammarat Province, as shown in Figure 1(a). The stone dust is crushed thoroughly, baked at 105 ± 5 °C for 24 hours and sieved through ASTM sieve No. 200 (aperture 75 μm) to obtain stone dust as shown in Figure 1(b), with the value of specific gravity of 3.16. Laterite soil (LS) was obtained from Ban Nam Phut laterite ponds, Khuan Thong Sub-District, Khanom District, Nakhon Si Thammarat Province. The laterite soil samples were reddish colour as shown in Figure 1(c). It was passed through ASTM sieve No. 4 (aperture 4.75 mm). The specific gravity is 2.73.

(a) Stone dust before crushing (b) Stone dust crushed (c) Laterite soil

Fig. 1 Raw materials

2.2 Mixture design and sample preparation

Design of interlocking block mixture proportion by using cement per lateral soil is 1:6 by weight [15]-[17]. The stone dust replacement with the percentage of the proportion of 10, 20 and 30 to the weight of Ordinary Portland Cement were utilized in this study by using water according to the optimum moisture content (OMC) from compaction test by standard proctor test method in accordance with ASTM D698 [18] of each mixing ratio. The mixing proportion is described in **Table 2.**

Table 2 Mix proportion of interlocking block of 6 sample bricks

Mixes	Cement kg	Stone Dust kg	Laterite soil kg	Water kg	Total Kg	OMC %
OPC	4.285	0	25.715	6.801	36.801	20.27
SD10	3.875	0.428	25.715	6.999	36.999	23.33
SD20	3.428	0.857	25.715	7.701	37.701	25.67
SD30	3.000	1.285	25.715	8.601	38.601	28.67

In the production of interlocking block specimen, mixed with stone dust replacement of the cement, the total weight of the mixture between the cement and the stone dust will be used. Each time, the quantity of laterite soil is consistently 30 kilograms. The weight of the mixture to put into the compactor is 5.8 kilograms per batch of production. The sample block formwork is a straight interlocking block. It has holes and spikes as hollow rounded flowers. It measures 12.5 centimeters wide, 10 centimeters high, and 25 centimeters long. The specimen was formed with a manual compression molding machine (Cinva-Ram), as shown in **Fig. 2**. It was then compressed by a hand operated toggle level and piston system, which exerted a minimum compacting pressure of about 2 MN/m^2.

Fig. 2 Cinva-Ram machine

In addition, the mixture should be compacted within 30 minutes after mixing with water to prevent the cement mixture from hardening before extrusion. Once extruded, the specimen is removed and stored in the shade for at least 1 day. Mortar is then filled into the specimen's holes with cement to sand ratio of 1: 2 and watered with a shower or aerosol spray. The specimen is cured by plastic cladding, as shown in **Fig. 3**, to prevent water from evaporating. Testing is conducted after curing until the desired age is reached.

Fig. 3 Curing interlocking block with plastic bags

2.3 Test Method

2.3.1 Testing the basic engineering properties of laterite soils

This is an initial property test conducted on laterite soil with the objective of using the acquired data for soil classification. The test details are outlined below:

- Specific gravity according to standard ASTM D 854 [19]
- Gradation according to standard ASTM D 2487 [20] and standard ASTM D 422 [21]
- Atterberg's Limit such as Liquid Limit (LL), Plastic Limit (PL) and Plasticity Index (PI) according to standard ASTM D 4318 [22]

2.3.2 The amount of water

Calculate the required water quantity for sample formation, adhering to the Standard Proctor Test (Optimum Moisture Content, OMC) in accordance with ASTM D698 [18].

2.3.3 Testing properties of interlocking block

This test assesses the physical and mechanical characteristics of interlocking block made with a stone dust mixture in comparison to interlocking blocks control and TCPS 602- 2004 standard [23]. The test details are outlined below:

- Water absorption and density according to standard TIS 57-2017 [24] at the incubation period of 28 days.

- Compressive strength according to standard ASTM C67 [25]. The blocks are tested at the curing ages of 7, 14 and 28 days. The specimen under test is shown in **Fig. 4**.

Fig. 4 Compressive strength test of interlocking block

3. Results and discussion

3.1 Basic engineering properties of laterite soil

Table 3 shows physical properties of laterite soil. It was found that this type of laterite soil had a specific gravity of 2.73. In general, laterite soil has a specific gravity between 2.55 and 3.0 [26] while laterite soil had a liquid limit of 39.28%, a plastic limit of 35.27% and a plastic Index of 5.01%. According to the tested results, the laterite soil had a relatively high ability to transform into a liquid. In other words, this type of laterite soil was in the state of too much water content and cannot be molded. According to the test results, the laterite soil used in this study was classified as quality class A-4 clay or silt according to the AASHTO system [27]. In contrast, according to the Unified Soil Classification System (USCS) [19], the value showed that the mixed size of laterite soil passing sieve No. 200 was 84.97%, liquid limit was 39.28% and plastic rating was 5.01%. It was considered that laterite soils classified as ML-OL were inorganic sand sediments and very fine sand, rock dust, fine sand, sand or clay sediment with a slightly sticky or inorganic sand sediment and clay soil mixed with organic sand sediment low toughness.

Table 3 physical properties of laterite soil

Physical Property	Results
Specific gravity	2.73
Moisture (%)	3.37
Percentage passing sieve No.4	94.70
Percentage passing sieve No.200	84.97
Liquid Limit; LL (%)	39.28
Plastic Limit; PL (%)	34.27
Plasticity Index; PI (%)	5.01

Laterite soil moisture content is 3.37%, which was acceptable in accordance with soil grade classification by ASTM 3282 standard [28]. Limited the moisture content of laterite soil it was less than 4%.

3.2 The results of the test for the optimum amount of water and dry density

Fig. 5 shows that the optimum water content tended to increase when the amount of stone dust increased. This scenario may occur due to the heightened water requirements associated with the use of stone dust. This is evident when the stone dust content exceeds that of cement, leading to an increased need for water to achieve surface glazing.

As the displacement ratio of stone dust increases, the demand of water also increases. When dry densities were considered, the stone dust 10% had the dry density higher than OPC. In contrast, the proportion of stone dust at 20% and 30% resulted in the lower dry densities.

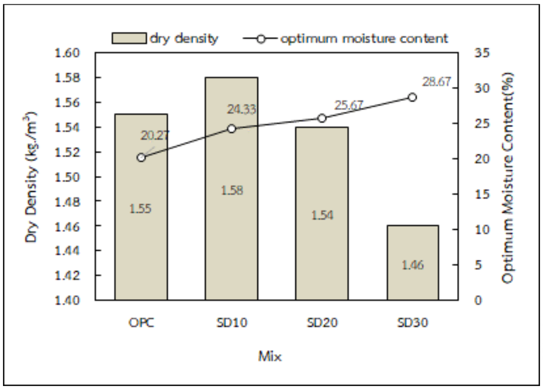

Fig. 5 The relationship between dry density and optimum moisture content

3.3 The results of interlocking block properties

3.3.1 General characteristics

The results of the general examination of the interlocking block mixed with stone dust revealed that all interlocking block, regardless of the proportion, displayed the reddish-brown color characteristic of laterite soil. The sample cube sizes or dimensions in accordance with the requirement [23] without blistering, expanding or contracting as shown in **Fig. 6**.

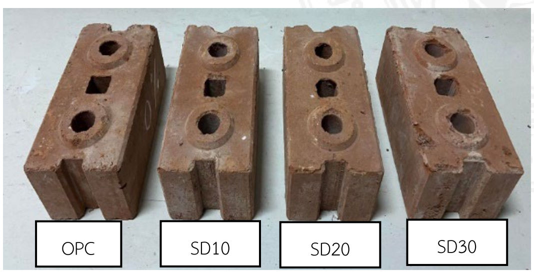

Fig. 6 Sample of interlocking block

For the mix SD30, the upper edge of the interlocking block was chipped. The result appeared consistent with the findings of [29], who found that it was easy to chip off the edges of interlocking block due to an insufficient amount of cement to bind the aggregate, which led to the less adhesive area around the edges of the blocks. Moreover, the flow of the ingredients into the mold was not smooth.

3.3.2 Water absorption and density

Fig.7 shows the results of the water absorption and density of the interlocking block. It can be seen that the water absorption decreased with the increasing in the amount of stone dust. As for the density of interlocking bricks, it revealed that interlocking block mixed with stone dust at 10% were higher than OPC, while an increase in stone dust at 20% and 30% generated the decreasing, which corresponds to the density of the designed mixture ratios. Relation between density and water absorption of interlocking block showed that the higher density caused the lower water absorption. It represented the low block's porosity, which had a low void ratio. In the meanwhile, the lower density of the interlocking block led to the higher void (Void Ratio). That induced the higher water absorption, which conformed to the findings of [30]. Their argument was that a reduced gap ratio resulted in a lower water absorption rate.

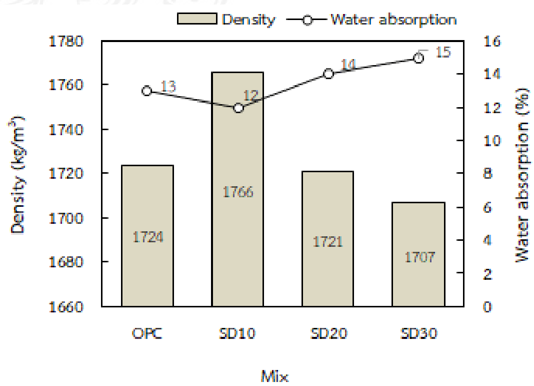

Fig. 7 The relationship between the density and water absorption of interlocking block

However, the water absorption in this study is lower than that specified in TCPS 602-2004 [23], which specifies that the water absorption must be less of 25%.

3.3.3 Compressive strength

As shown in **Fig. 8**, the compressive strength increased with increasing of the curing age due to the hydration reaction occurring continuously over the curing period [31], which were in line with the results of [32]. They showed that the rate of hydration in the interlocking block affected the brick strength and stability.

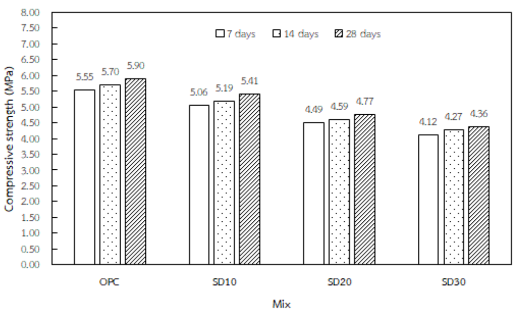

Fig. 8 Compressive strength test results of interlocking block

The compressive strength tended to decrease with an increase in the amount of stone dust. The increase in stone dust by 10% decreased the compressive strength around 8%, which is consistent with the research results of [10]. The analysis of the substitution of stone dust for cement displayed that the chemical compounds which strengthen the concrete were reduced. The compressive strength of interlocking block was compared to the TCPS 602-2004 [23], which describes that the average load-bearing interlocking block must not be less than 7.0 MPa and the average non-load bearing type must not be less than 2.5 MPa at the test ages of 7, 14 and 28 days. The comparison showed that the interlocking block in all mix ratios and all curing ages meet the above standard.

4. Conclusions

In this study, the investigation of interlocking block mixed with stone dust focused on a mixture ratio of 1 part Portland cement type 1 to 6 parts laterite soil by weight. The stone dust content in the interlocking block varied at 0, 10, 20, and 30 percent by weight of the cement. The results of the research can be summarized as follows.

1. The amount of stone dust affects the water demand of the interlocking block; increasing the amount of stone dust increases the water demand of the interlocking block.
2. The amount of stone dust in place of cement at less than 10% caused the density of interlocking block to be greater than that of OPC. In contrast, if the amount of stone dust is increased to 20% and 30%, the density of interlocking block is reduced and lower than that of OPC.
3. The higher the amount of stone dust is, the lower the compressive strength of the interlocking block and the higher the water absorption value are.
4. From the results of this research, the optimum ratio of stone dust contents is 30%, which had the required properties as specified in TCPS 602-2004 [23], non-load bearing type. It has lower density properties than OPC and will benefit its application in construction. It is convenient to move by workers and reduces the weight the exerted on the structure. Finally, the further studies should be done on the heat transfer properties, corrosion and shrinkage of interlocking block.

5. Acknowledgements

The researcher would like to thank Rajamangala University of Technology Srivijaya for supporting the research fund for the fiscal year's income statement for the year 2020. Including, thank you for the

Division of Engineer, College of Industrial Technology and Management, Rajamangala University of Technology Srivijaya that support the use of the equipment.

6. References

[1] Thailand Institute of Scientific and Technological Research (TISTR). (2020, Jan 9). Interlocking block technology. [Online]. Available: https://technologyblockprasan.com/803/

[2] K, Chaimoon, "Compressive Strength and Behavior of Interlocking Block Masonry under Eccentric Loading" Research and Development Journal, vol. 21, no. 2, pp. 6-14, 2010.

[3] E. Gartner, "Industrially interesting approaches to "low-CO_2" cements," *Cement and Concrete research*, vol. 34, no. 9, pp. 1489-1498, 2004.

[4] A. M. Rashad. and S. R. Zeedan, "The effect of activator concentration on the residual strength of alkali-activated fly ash pastes subjected to thermal load," *Construction and Building Materials*, vol. 25, no. 7, pp. 3098-3107, 2011.

[5] Breakthrough Energy. (2022, Aug 12). Chement's patent-pending technology eliminates all CO_2 emissions in cement production. [Online]. Available: https://breakthroughenergy.org/fellows-project/chement/; 2022

[6] The Office of Industrial Economics. (2021, Jan 29). Industry statistics report. [Online]. Available: https://i.index.oie.go.th/industrialStatisticsReport.aspx.; 2021

[7] A. Leeanansaksiri, W. Phochan and T. Pongnum, "Development of Interlocking Lightweight Cement Blocks from Sludge Mixed Pozzolan Material," *Engineering Journal of Research and Development*, vol. 31, no. 1, pp. 135-143, 2020.

[8] K. Paopongpaiboon, K. Boonserm, V. Horsakulthai and P. Chindaprasirt, "Development of Interlocking Block Blended with Biomass Ash for Using As a Insulating Material," *Engineering Journal of Research and Development*, vol. 30, no. 2, pp. 95-105, 2019.

[9] T. Klathae, "Utilization of crushed oyster shell on interlocking block," *RMUTP research Journal*, vol. 11, no. 2, pp. 167-177, 2017.

[10] C. Choosakul and K. Yongsata, "High Strength Concrete Using Decomposed-Stone Dust," in *Proceeding of the Annual Concrete Conference 12*, Thailand, 2018, pp. MAT01-MAT06.

[11] *Standard specification for coal fly ash and raw or calcined natural pozzolan for use in concrete*, ASTM C 618, 2003.

[12] I. B. Muhit, M. T. Raihan and MD. Nuruzzaman, "Determination of mortar strength using stone dust as a partially replaced material for cement and sand," *Advance in Concrete Construction*, vol. 2, no. 4, pp. 249-259, 2014.

[13] Department of Industrial Works. (2021, Feb 3). Factory information. [Online]. Available: https://userdb.diw.go.th/results1.asp.

[14] *Standard specification for Type 1 Portland cement*, TIS 15, 2004.

[15] S. Assiamah and H. Danso, "Effects of Sand on The Properties of Cement-Laterite Interlocking Blocks," in *Proceeding of the West Africa Built Environment Research (WABER) Conference*, Ghana, 2021, pp. 569-578.

[16] P. Khamput, "Development of Light-weight Interlocking Block Product

form EVA Plastic Wastes," *Thai Environmental Engineering Journal*, vol. 30, no. 3, pp. 57-64, 2016.

[17] N. Intaboot, "Innovation of Interlocking Block Mixing with Biomass for Sound Absorption and Thermal Conductivity in Thailand," *Journal of Advanced Concrete Technology*, vol. 18, no. 8, pp. 473-480, 2020.

[18] *Standard Test Methods for Laboratory Compaction Characteristics of Soil Using Standard Effort*, ASTM D 698, 2006.

[19] *Standard Test Methods for Specific Gravity of Soil Solids by Water Pycnometer*, ASTM D 854, 2006.

[20] *Standard Practice for Classification of Soils for Engineering Purposes (Unified Soil Classification System)*, ASTM D 2487, 2017.

[21] *Standard Test Methods for Particle - Size Analysis of Soils*, ASTM D 422, 2007.

[22] *Standard Test Methods for Liquid Limit, Plastic Limit, and Plasticity Index of Soils*, ASTM D 4318, 2005.

[23] *Thai community product standard of interlocking block*, TCPS 602, 2004.

[24] *Hollow Loadbearing Concrete Masonry Units*, TIS 57, 2017.

[25] *Standard methods of sampling and testing brick and structural clay tile*, ASTM C67, 2007.

[26] M. Gidigasu, "Laterite Soil Engineering: Pedogenesis and Engineering Principles," 2nd ed., Amsterdam: Elsevier, 2012.

[27] *Standard Specification for Classification of Soils and Soil–Aggregate Mixtures for Highway Construction Purposes*, AASHTO M145-91, 2012.

[28] *Standard Practice for Classification of Soils and Soil-Aggregate Mixtures for Highway Construction Purposes*, ASTM D 3282, 2015.

[29] A. Boksuwan and P. Khamput, "Interlocking Block Product for Community Enterprises from Anhydrite Rock Fragments," in *Proceedings of 3rd National RMUTR Conference*. Thailand, 2018, pp. 19-26.

[30] N. Janpetch and W. Kokkamhaeng, "The Test of The Compressive Strength of an Interlocking Block of Thailand," *RMUTSB ACADEMIC JOURNAL*, vol. 4, no. 2, pp. 196-206, 2016.

[31] P. Chindaprasirt and C. Jaturapitakkul, "Cement pozzolan and concrete," 7th ed., Bangkok: Thailand Concrete Association, 2008.

[32] P.O. Awoyera and I.I. Akinwumi, "Compressive strength development for cement, lime and termite-hill stabilized lateritic bricks," *The International Journal of Engineering and Science*, vol. 3, no. 2, pp. 37-43, 2014.