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Research article

Effect of Decomposed-Stone Dust on Properties of Concrete

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Abstract: The objective focused on the study of shrinkage behavior of concrete using Decomposed-Stone Dust to replace Portland cement type 1 in the ratio of 10, 15, and 20 percent by weight of binder as well as designing compressive strength at 280 kg/cm². Testing the formation time, shrinkage behavior, and compressive strength of concrete was compared with the concrete using Portland cement type 1. The study found that the concrete using Decomposed Stone Dust was an increased formation period in accordance with the amount of replaced Decomposed-Stone Dust. Autogenous shrinkage, dry shrinkage, and compressive strength of concrete mixed with Decomposed-Stone Dust were less than control concrete. In all mixing ratios, the ratio of 20% replacement of Portland cement dust was the most suitable for this study. The initial formation time was 155 minutes. The final formation period was 305 minutes. The autogenous shrinkage was 312 microns, the dry shrinkage was 699 microns and compressive strength was 286 kg/cm² respectively at age 28 days.

Keywords: Shrinkage Concrete, Compressive Strength, Decomposed-Stone Dust, Natural Pozzolan

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1. Introduction

Decomposed stone is a raw material found in volcanic, granite, feldspar, or kaolin sites. Thailand found several sources of decaying stone. However, the most popular sources used in the ceramics industry are Lampang, Lopburi, Kanchanaburi, and Phetchaburi, as known as the trade name of it in Pottery Stone. In general, the main mineral structure of a decaying stone consists of quarts and mica. (White Mica; $K_2O{\cdot}3Al_2O_3{\cdot}6SiO_2{\cdot}H_2O$). Quarts are highly fireproof with no stickiness, including incapable of melting. On the other hand, mica has properties like kaolin by quality of being sticky. Because of that quality, it improves the flow conditions of decomposed stone, the decomposed stone's melting point is about 1,150-1,300 °C. Decomposed stone is a mineral that yields silica, alumina, and potash in the optimum ratio with the chemical composition in the structure as shown in Table 1 [1] Decomposed stone dust is obtained by crushing the rock, which has properties containing Class N pozzolans [2] as ASTM C 618 [3].

From the study of [2], it was found that decomposed stone dust can be used as a substitute for type 1 Portland cement in mortars for construction and plastering work. The mortar mixed with 25% of the decomposed stone dust had the highest compressive strength. Mortar mixed with 20% of the decomposed stone dust had the highest tensile strength. According to a study of [4] in high-strength concrete, the decomposed stone dust can be used as a substitute for the Portland cement type 1 to a ratio of 10% with a compressive strength of 517 kg/cm^2 at age 28 days.

Table 1. The amount of chemical elements in the structure of decomposed stone

Chemical composition (%)	Lampang [1]	Lopburi [1]	Surat Thani [2]
SiO_2	76.61	75.88	30.07
Al_2O_3	13.09	11.69	19.86
Fe_2O_3	0.35	0.81	13.67
SO_3	-	-	6.29
MgO	0.01	< 0.01	2.47
CaO	0.15	0.20	16.78
Na_2O	5.20	3.67	1.31
K_2O	1.59	4.74	2.12
TiO_2	0.05	0.13	-
P_2O_5	< 0.01	< 0.01	0.21
MnO_2	0.02	0.01	-
Cr_2O_5	0.01	<0.01	-
LOI	3.92	3.67	5.80

The cracking from the concrete shrinkage is one of the problems with the concrete structures. This is because cracks affect the stability and beauty of the structure. Cracking concrete allows the water or other substances to penetrate the concrete surface and react with the water and reinforcement. Resulting in the reinforcement rusting reduced cross-sectional area. That resalt influenced to be decreasing of the tensile strength of the reinforcing steel, including increasing of the deflection and will affect the problem of using the building in the long-term. Concrete cracking usually occurs in early concrete life by having low-strength concrete shrinkage cracking, which has a complex mechanism. It depends on many factors: including independent contraction shrinkage rate pull creep conditions of retention elastic modulus [5-6]. There are many types of concrete shrinkage. The contraction that has a great effect on cracking is auto genius contraction and dry shrinkage. The cracking caused by the concrete shrinkage is the result of the automatic shrinkage and the dry shrinkage that are coexist. Shrinkage of concrete alone cannot cause concrete to crack. But if the recoil is retained, whether it is retaining from the internal reinforcement or an external structure. All cause a seizure within the concrete when the concrete is retained, a tension unit is created. When the tensile strength unit is greater than the concrete tensile strength, the concrete will crack [7].

2. Materials and Methods

2.1 Research materials

2.1.1 Binder

This research was using Portland Cement Type 1, SCG brand of Siam Cement Company Limited, produced in accordance with TIS 15, Volume 1 [8] and decomposed stone dust from rotted stone wells in DonSak district Suratthani Province by using decomposed stone material to grind thoroughly.

2.1.2 Aggregates

Coarse aggregates using limestone with the maximum size of 3/8 inch, the value of 2.77, water absorption of 0.49%, the weight of 1,512 kg/m^3, and fineness modulus (FM) is 7.47. The fine aggregate used coarse sand with specific gravity (Saturated Surface Dry) of 2.60, water absorption of 0.48%, unit weight of 1,590 kg/m^3 and FM is 3.10. Both types of aggregates are aggregate grading in accordance with standard ASTM C33 [9].

2.2. Mixture design and sample preparation

Concrete sample preparation by replacing the decomposed stone dust material to replace Portland Cement Type 1at a ratio of 10, 15, and 20% by weight of the binder. Design concrete mix according to standards ACI 211.1-91 [10] .The maximum compressive strength is determined at the age of 28days (fc′) equals 280 kg/cm ^{2}which is suitable for medium-sized buildings and as it is used for most low rise structural buildings [11]. The concrete mixing design is shown in Table 2.

Table 2. Concrete Mixing Designs in This Study

Code	Content (kg/m^3)				
	Cement	**DSD**	**Sand**	**Rock**	**Water**
OPC	420	0.00	866	924	162
DSD10	375	42	866	924	162
DSD15	357	63	866	924	162
DSD20	336	84	866	924	162

Note :OPC = Concrete mixed with Ordinary Portland Cement Type1
DSD10 = Concrete mixed with Decomposed Stone Dust 10%

2.3 Test method

2.3.1 Fineness of decomposed stone dust test by sieve number 325 according to ASTM C430 [12].

2.3.2 Setting time of concrete was sifted through a No.4 sieve and placed into a cube-shaped formwork and size 15 x 15 x 15 centimeter by tested in accordance to ASTM C403 [13]. Test for the collapse value of fresh concrete was according to ASTM C143 [14].

2.3.3 Dry shrinkage test by applying from the ASTM C596 [15]. The model was removed at 24 hours and then, incubated in water for 7 days. The temperature during incubation was 30 ± 2 °C. When the curing has finished, then removed the sample from the water and dried the surface with a cloth. The length of the sample was taken against a standard fixed-length metal rod. Which is the default length the incubated parts were taken in the air, the average temperature was 30 ± 2 °C. The length of the sample was taken against a standard fixed-length metal rod. The air curing life was 7 to 28 days to determine the percentage of dry shrinkage over the curing life. Also, the values measured at different ages were used to calculate the percentage of dry shrinkage.

2.3.4 Autogenous shrinkage test is compliant ASTM C157 [16] measured for the shrinkage of concrete bar sizes 7.5 x 7.5 x 28.5 centimeter. Test by removing the 24 -hour old model and measuring the initial length samples are aged for 1 day, then incubated by plastic wrap for 1 to 28 days and stored in the incubation room. The shrinkage measurement was started as an applied method from the same standard used for the dry shrinkage measurement.

2.3.5 The compressive strength test with cylinder 15 × 30 centimeter mold. The samples were demolded 24 hours after casting. The cylinder was tested at the age of 7 days, 14 days, and up to 28 days monitoring stag after the wet curing process at the curing tank in accordance with procedures according to ASTM C39 [17]. The compressive strength reported in this article is the average obtained from 3 test samples.

3. Results and Discussion

3.1 Fineness of decomposed stone dust

Resolution test results of decomposed stone dust It was found that the average percentage of retention on a wet sieve No. 325 standard sieve was 27.70%. The obtained values are within the criteria specified by ASTM C618 [3], which must be less than 34%.

3.2 Setting time of concrete

Table 3shows the time of the formation of concrete samples. The results showed that the increase in the decomposed stone dust resulted in an increased time of formation. Due to the increased replacement of pozzolanic materials, the cement content is low, resulting in an increased formation time, C_3S will decrease with the decrease of Portland cement. This substance allows concrete to be formed in a short time. It relates to the research of [18].

Table 3. Setting Time and Slump of fresh concrete blended with decomposed stone dust

Code	Setting Time (min)			Slump (cm)
	Initial	Finished	Elapsed	
OPC	119	268	149	8
DSD10	127	274	147	10.5
DSD15	140	289	149	11.5
DSD20	155	305	150	12

3.3 Dry shrinkage

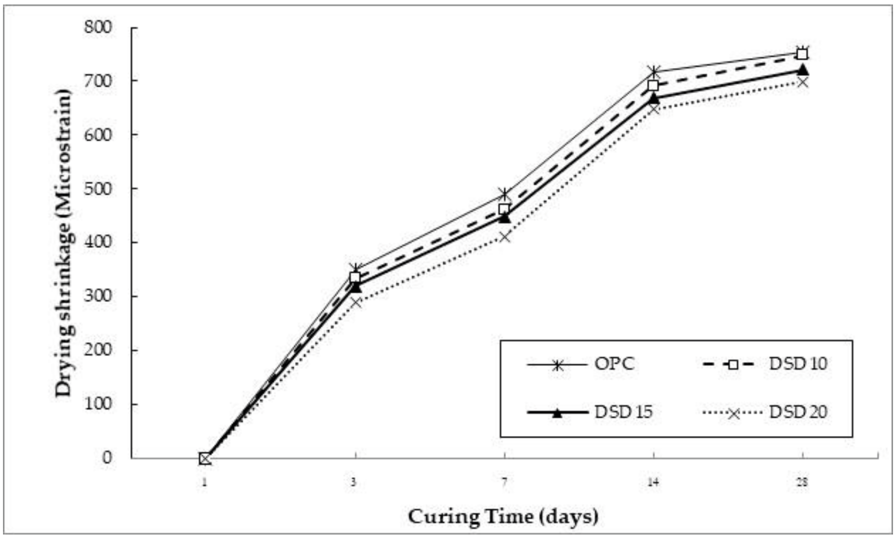

Figure 1. Dry shrinkage of concrete

Figure 1 shows the dry shinkage of concrete was found that concrete mixed with decomposed stone dust tends to shrink less than control concrete, the shrinkage of concrete increased with the increase in curing time for both controlled concrete and decomposed stone dust mixture. The contraction rate occurs rapidly at the beginning. And begin to decline over time. This is because, initially, large volumes of free water could easily be moved outside through the capillary channel until the water content in the gel structure and calcium silicate hydrate (C-S-H) is released, but the evacuation capacity is very low [19]. Due to the structure of the gel and the C-S-H (Restrained) to be used at an increased time. Increased hydration results in an increased amount of C-S-H in concrete, that is, the capillary cavity is smaller, water or moisture makes it difficult to move. Up results in, therefore the shrinkage rate is lower until the shrinkage is stable.

3. 4Autogenous shrinkage

The autogenous shrinkage behavior of concrete mixed with decomposed stone dust compared with control concrete overall is presented in Figure 2. It can be seen that concrete containing decomposed stone dust had lower shrinkage than control concrete. The shrinkage value decreased as the amount of cement replacement with decomposed stone dust increased. Increasing the percentage of replacing cement with decomposed stone dust is equivalent to reduce the amount of cement in the concrete. As a result, the hydration reaction decreases, and the free water content in the concrete increases, Thus, causing the shrinkage of autogenous [20].

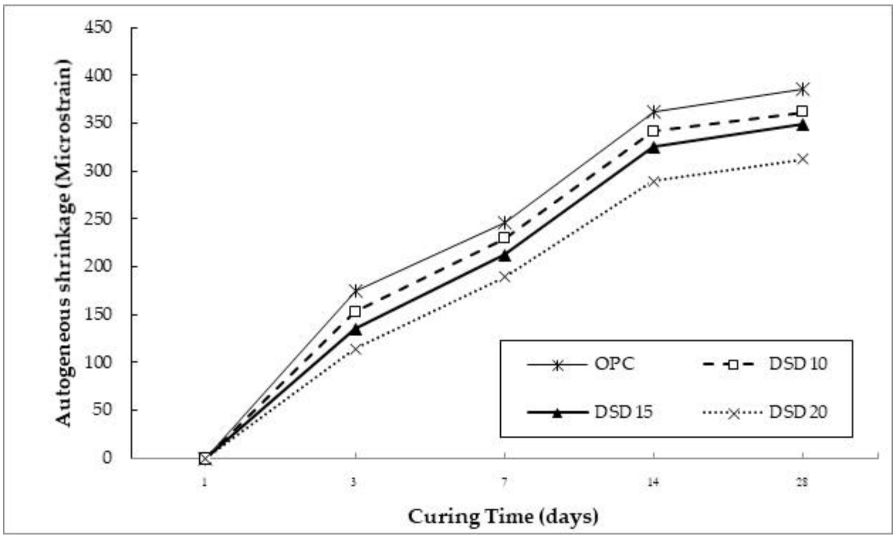

Figure 2. Autogenous shrinkage of concrete

3.5 Compressive Strength

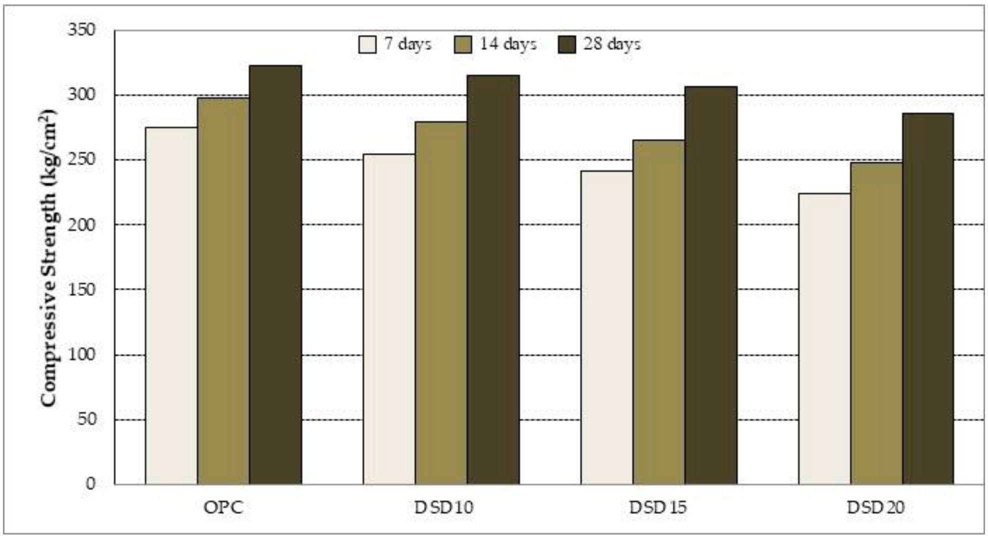

Figure 3. Compressive Strength of concrete

Figure 3 shows the results of testing the compressive strength of concrete. Increasing the amount of decomposed stone dust will reduce the compressive strength of concrete. Developing the compressive strength of concrete with curing age, it can be seen that the control concrete develops regularly. But in the concrete mix with decomposed stone dust, the early compressive strength development is relatively lower because of the absence of pozzolanic reaction, but after 14 days the compressive strength development rate will be higher. This is because the pozzolanic reaction develops more as the curing age increases [21]. For replacement of 10% and 15% of decomposed stone dust gives compressive strength close to those of OPC at 28 days.

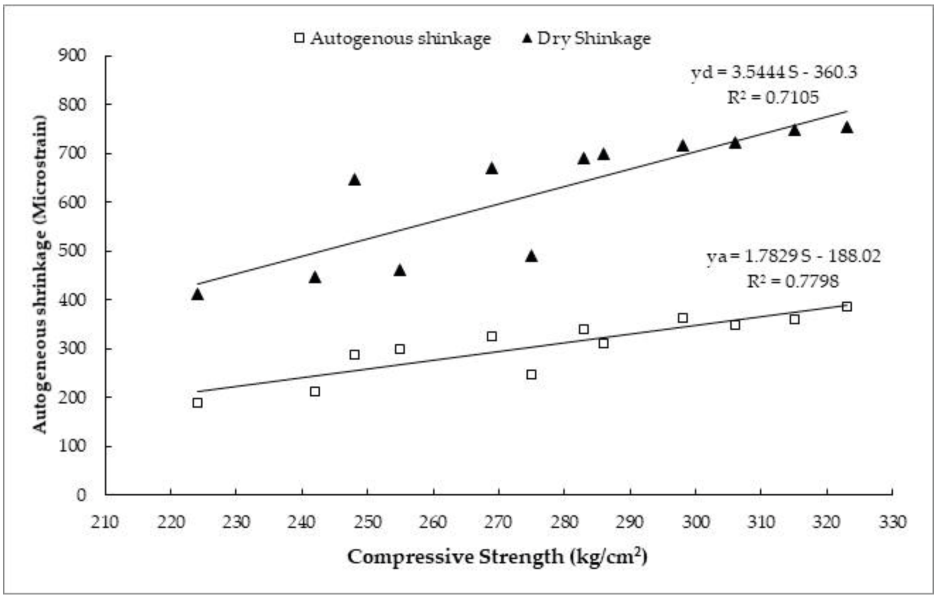

Figure 4. Relationship between Compressive Strength of concrete and Dry shrinkage, Autogenous shrinkage. (yd: dry shrinkage, ya: autogenous shrinkage, S: compressive strength, R^2: coefficient of correlation)

Figure 4 shows this linear relationship for various deformations of dry shrinkage and autogenous shrinkage with a relatively acceptable correlation coefficient. It is established that this relationship is sufficient for ordinary cement and natural pozzolan as reported by the researcher [22]. As the results show, it is clear that the relationship of autogenous shrinkage to compressive strength is well acceptable when the correlation coefficient is higher.

Figure 5-6 represents the dry shrinkage and autogenous shrinkage with compressive strength for each code of concrete. From these results, it will be shown that when the concrete has a compressive strength of more than 300 kg/cm^2, the cavitation decomposed stone dust mixture results in lower autogenous shrinkage of DSD than the OPC. And it can be seen that when the concrete still has a strength value of less than 280 kg/cm^2, the decomposed stone dust mixture increases the dry shrinkage. But when the strength is beyond this, the decomposed stone dust mixture will decrease the dry shrinkage value. Once this strength is exceeded the concrete contains decomposed stone dust, and when the compressive strength exceeds 300 kg/cm^2 the dry shrinkage of the decomposed stone dust concrete is also lower than that of the OPC with autogenous shrinkage. This result is in agreement with those reported by Armed et al. [22].

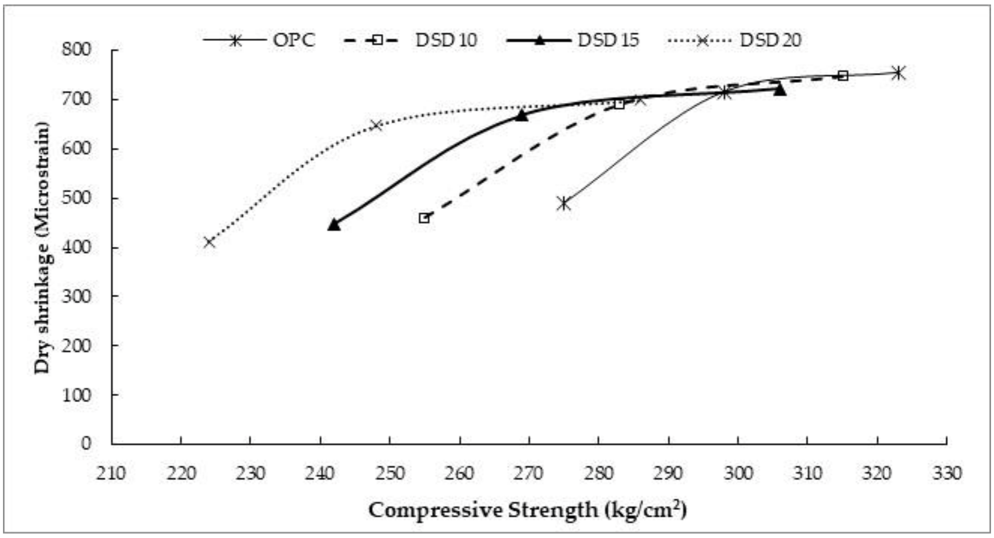

Figure 5. Variation of dry shrinkage according to compressive strength for several replacement rates of decomposed stone dust.

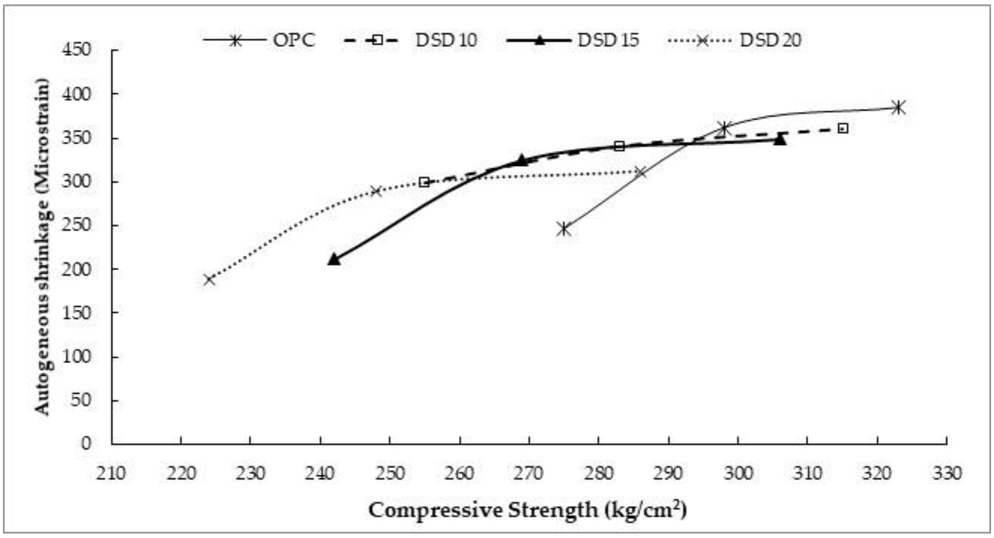

Figure 6. Variation of autogenous shrinkage according to compressive strength for several replacement rates of decomposed stone dust.

4. Conclusions

The test results are obtained from the research can be summarized as follows.

1. Concrete replacing cement with decomposed stone dust, helps to increase the formation time of concrete.

2. Concrete replacing cement with decomposed stone dust, reduces dry shrinkage of concrete.

3. Concrete replacing cement with decomposed stone dust, reduces the autogenous shrinkage of concrete.

4. The dry shrinkage has a greater shrinkage of the concrete sample than the autogenous shrinkage because the concrete sample exhibits rapid and constant loss of free water even at an extended curing life. Whereas the hydration reaction has a slower and lesser effect on the shrinkage of the concrete sample at the same time.

5. The partial replacement of cement with decomposed stone dust results in a decrease in compressive strength and the value decreased as the amount of decomposed stone dust increases.

6. The shrinkage of concrete varies with the compressive strength of concrete. When the concrete has a compressive strength of 300 kg/cm^2, the shrinkage behavior between the decomposed stone dust concrete and OPC will change.

7. Concrete replacing cement with 20% decomposed stone dust was the most suitable in this study. The initial formation time was 155 minutes, the final formation time was 305 minutes. The elapsed time was 150 minutes. From all the formation time mentioned before a curing time of 28 days, the result of autogenous shrinkage was 312 microns, the dry shrinkage value was 699 microns and the compressive strength was 286 kg/cm^2, respectively.

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Author Contributions:

Funding:

Conflicts of Interest:

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