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INVESTIGATION OF STRENGTH OF CONCRETE COMPRISING SIEVED BASALT DUST AS SAND SUBSTITUTION

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บทคัดย่อ

งานวิจัยนี้มีวัตถุประสงค์เพื่อศึกษากำลังอัดของคอนกรีตที่ใช้หินฝุ่นบะซอลต์คัดขนาดเป็นส่วนผสมแทนทราย รวมไปถึงการศึกษาการประยุกต์ใช้ในงานวิศวกรรมโยธา ทั้งนี้จะใช้หินฝุ่นบะซอลต์คัดขนาดที่อัตราส่วนร้อยละ 20 40 60 80 และ 100 (แทนทรายทั้งหมด) โดยน้ำหนัก การวิจัยทดลองในโครงการนี้จะศึกษาจากการเปรียบเทียบ ระหว่างผลของคอนกรีตที่ผสม อัตราส่วนน้ำต่อปูนซีเมนต์ (W/C) ที่ 0.45 กับ 0.65 ทั้งนี้ปรากฏว่าการรับกำลังอัดของคอนกรีตที่ผสม W/C 0.45 และ 0.65 ที่อายุการบ่มน้ำ 28วัน ให้ค่ากำลังอัดสูงสุดที่อัตราส่วนการใช้หินฝุ่นบะซอลต์คัดขนาดแทนทราย 60% ค่ากำลังอัดสูงสุดที่ได้ มีค่า 350 ± 4.50 กก./ตร.ซม. สำหรับคอนกรีตที่ W/C 0.45 และ 299 ± 10.44 กก./ตร.ซม. สำหรับคอนกรีตที่ W/C 0.65 โดยที่ค่ากำลังอัด 350 ± 4.50 กก./ตร.ม. เป็นค่าที่ให้ความน่าเชื่อถือกว่า และมีความเสถียรกว่า หากเปรียบเทียบระหว่างคอนกรีตที่ผสมตามปกติ กับคอนกรีตที่ผสมหินฝุ่นบะซอลต์คัดขนาดแทนทราย ทั้งสองส่วนผสมที่กำลังอัดสูงสุด ปรากฏว่า คอนกรีตที่ผสมตามปกติมีค่ากำลังอัดสูงกว่า 1.1% และ 4.2% ตามลำดับ นอกจากรายละเอียดด้านกำลังอัดตามที่กล่าวมาแล้วนั้น ในส่วนของการประยุกต์ใช้ หากพิจารณามาตรฐาน มยพ.1101-52 ของกรมโยธาธิการและผังเมือง ที่กำหนดค่ากำลังอัดประลัยต่ำสุด ที่ 150 180 210 และ 240 กก./ตร.ซม.สำหรับคอนกรีตประเภท ค.1 (งานก่อสร้างทั่วไป) ค.2 ค 3 และ ค4 จะเห็นว่า คอนกรีตที่มีค่ากำลังอัด 350 กก./ตร.ซม. มีศักยภาพสูงที่จะสามารถประยุกต์ใช้ในงานโครงสร้างทางโยธาด้านต่าง ๆ

ABSTRACT

The research objectives are to investigate the compressive strength of the concrete partly composed of sieved basalt dust aggregate as sand substitution, as well as to look into its application in civil engineering. The sieved basalt dust ranges from the ratios of 20, 40, 60, 80 and 100 percentages (only sieved basalt dust aggregate) by weight. The investigation is through the comparison between the concrete mixed at the water-cement ratios (W/C) 0.45 and W/C 0.65. The experimental results have shown that the concrete of both mixing ratios provides the highest compressive strength at 60 percentage of sieved basalt dust in place of sand. The peak strengths are 350 ± 4.50 ksc for W/C 0.45 and 299 ± 10.44 ksc for W/C 0.65. The strength 350 ± 4.50 ksc is both more reliable and more consistent. In comparison between the normally mixed and the two mixing ratio concretes, the former has higher strength about 1.1% and 4.2% respectively. For the application viewpoint, the standard of the Department of Public Works and Town & City Planning (DPT) 1101-52 has specified the lowest ultimate compressive strength to be 150, *180, 210 and 240 ksc for the concrete type K1 (general civil construction) K2, K3 and K4. Therefore, this concrete with the compressive strength of 350 ksc has high potential to be applied in practical use for various civil structures.*

KEYWORDS: Sieved, Basalt dust, Sand, Aggregate, Concrete, Compressive strength

1. Introduction

Concrete is normally a main component for most civil engineering structure. The civil engineering work plays crucial role on the development and progress of human society. The civil structural constructions are for example house building, schools, industrial plants, infrastructures for transportation (road, tunnel, motor way, high-speed train etc.), and they continuously expand. In general, the civil construction mostly requires the structure or foundation made of concrete, the material that is able to be designed for any load bearing, durable and last long [1].

The normal constituents of concrete mixture are cement, sand and rock aggregate that needs to be inert materials and non-reactive to the cement paste. Their functions are to be filler in the paste volume of about three quarters, aiming at lowering the cost of concrete while maintaining the same property of concrete [2]. Also, there are researches and studies to find any new method or technology that may help make lower cost and more convenient use for the concrete.

The basalt dust aggregates are from the crushing plants in Buriram, a southerly eastern province in Thailand. The feed materials to the plants are blasted rock from the mining faces of basalt quarries. This type of aggregate is only one out of four normal production outcomes of the plants: the aggregates of the sizes 1, 3/4, 3/8 and 3/16 inch (dust) [3]. All these aggregates are for civil construction as well as for concrete. However, the dust has only few application uses. For most quarries, it becomes waste or the burden cost of removing as well as stockpiling.

Based on the above mention, the purposes of this research project are to investigate the compressive strength of concrete that comprises in its mixture the sieved basalt dust aggregate in different proportions as sand substitution, to examine the potential application use in civil engineering structures for the partly sand replaced concrete, and to study the engineering properties of basalt dust aggregate.

2. Test Specimens and Procedures

The concrete specimens are cylindrical in shape according to ASTM C192 [4], which are 15 cm in diameter and 30 cm in height (Figure 1(a)). The composition of specimens comprises water, cement, coarse aggregate and fine aggregates of sand and some basalt dust that partly substitute sand in the proportions of 20, 40, 60, 80 and 100 percent (only basalt dust and no sand) by weight. The coarse aggregates are crushed limestone of the size 3/4 in from Saraburi, and the gradation is complied with ASTM C136 [5]. The sand as fine aggregate has the grainsize distribution conforming to ASTM C33 [6]. The basalt dust aggregate from Buriram is sieved (no.4 to no.100) before mixing. The cement paste is the combination of Portland cement type 1 and public water.

The water cement ratios (w/c) for mixing concrete are 0.45 and 0.65 by weight, and the mixture is 1:2:4 (cement: sand: aggregate). After curing for 28 days, the specimens will be under testing to determine the compressive strength (Figures 1(b) and 1(c)). The experimental procedure follows the ASTM C39/C39M [7] standard practice. The compressive strengths of the specimens are measured by axially loading on the cement cylinder. The specimens are loaded at the constant rate of 1.4-3.4 kg/cm^2/second until failure. The maximum failure loads are recorded to determine the compressive strengths of the specimens. Figure 1(d) shows an example of failure specimen after loading. At first, the number of tested specimens is 84 pieces. After obtaining the experimental results, it takes additional 28 pieces, in order to analyze and verify the experimental outcomes of compressive strengths. Thus, the total number of all specimens is 112 pieces.

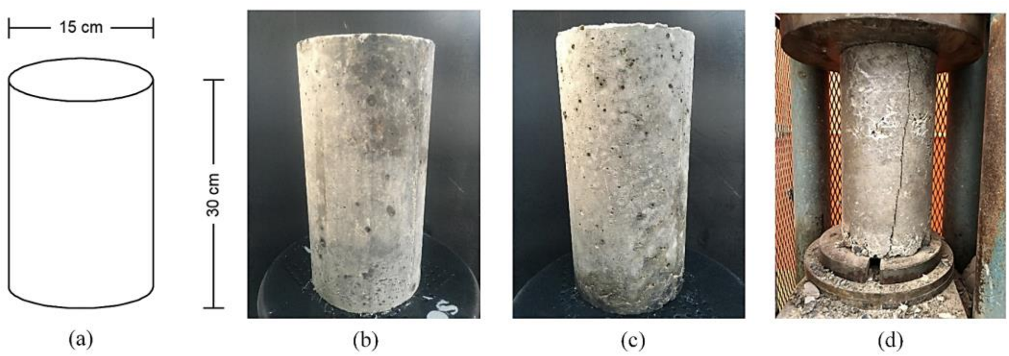

Figure 1 Shape and dimension of tested specimen in compliance with ASTM C129 (a), concrete specimens with W/C = 0.65 (b) and with W/C = 0.45 (c), and failure specimen after loading (d).

3. Experimental Results

The test results are the compressive strengths of partly sand substituted concrete mixed at w/c = 0.45 and 0.65, as well as the engineering properties of the basalt dust aggregate.

3.1 The engineering properties of sand and the basalt dust aggregate are as follows.

3.1.1 The sieve analysis indicate that grainsize distribution of the basalt dust aggregate is coarser than the one of sand (Figure 2). The gradation of sand is within the standard range ASTM C33 [6], while the basalt dust is so coarse that it slightly goes out of the ASTM range. The fineness modulus of sand and the sieved basalt dust are 3.62 and 2.70, respectively.

3.1.2 The specific gravity and the water absorption of the sieve basalt dust are 2.80 and 3.084.

3.2. The results of the compressive strength of partly sand substituted concrete are the followings.

3.2.1 For the 28-day curing concretes mixed at w/c 0.45 and w/c 0.65, both have the highest compressive strength when composed of the sieved basalt dust 60% in place of sand. The peak strengths are 350 and 299 ksc (Figures 3 and 4)

3.2.2 The compressive strengths of concrete with w/c 0.45 and 0.65 are in the range of 198 to 354 ksc, and 191 to 312 ksc (Figures 3 and 4).

3.2.3 The normally mixed concrete has higher strengths about 1.1 % and 4.2 %, compared to both peak strengths.

Among compressive strengths of all tested specimens as shown below, what should be investigated further are the peak 350 ksc and 299 ksc . The issues worth investigating more are the reliability and variance of both values as well as the practical application in civil engineering.

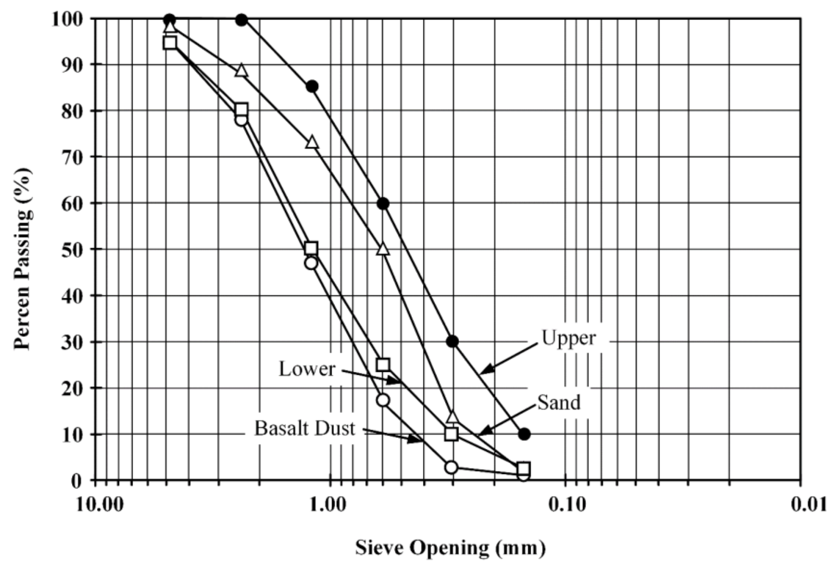

Figure 2 Gradation curve of sand, sieved basalt dust and standard range ASTM C33

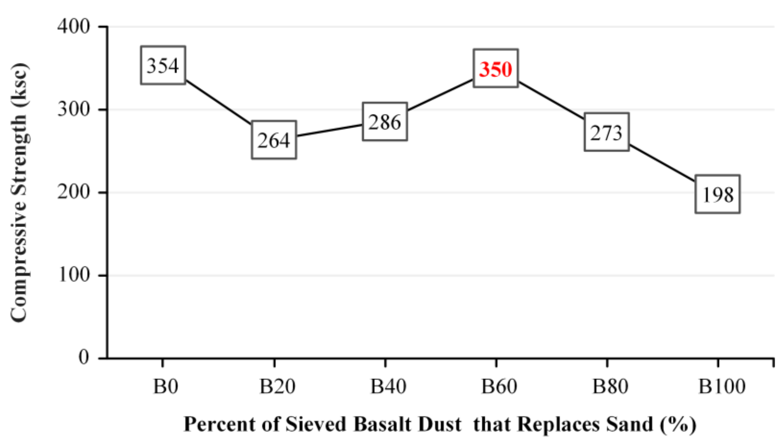

Figure 3 Compressive strength of partly sand substituted concrete by sieved basalt dust at w/c = 0.45

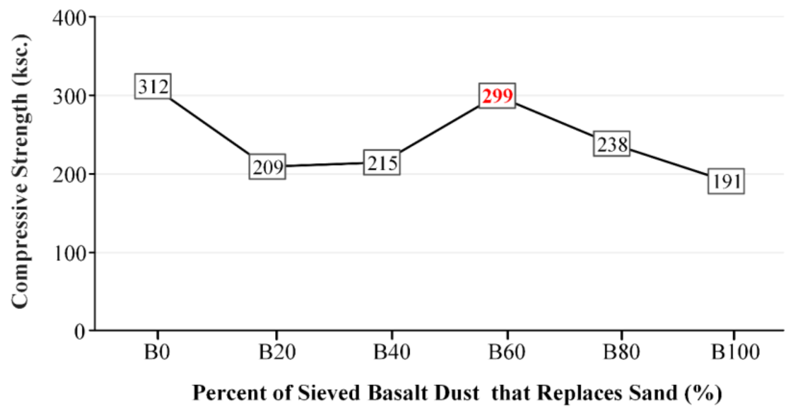

Figure 4 Compressive strength of partly sand substituted concrete by sieved basalt dust at w/c = 0.65

The proportions to replace sand on the ranges of 20, 40, 60, 80 and 100 percent are rather broad, and therefore the narrower intervals of 50 and 70 as sand replacement should help verify the peak strengths (Table 1 and 2, and Figures 5 and 6). The issue to be further examined is the variance of the highest compressive strengths obtained from the test results. Hence, it requires the calculation of standard deviation (S.D.) (Tables 3 and 4). The last point to consider is the application use. Below is the Standard of the Department of Public Works and Town & City Planning (DPT) 1101-52 [8] (Table 5) that specifies the lowest ultimate compressive strength (ksc) for each type of concrete for construction.

Table 1 Experimental results of the compressive strength and the slump of concrete at w/c = 0.45

Curing time(days)	Proportional percentage of sieved basalt dust substituted for sand			
	0	50	60*	70
28	354	308	350	298
Slumping value of the concrete partly composed of sieved basalt dust				
Percent of substitution	0	50	60	70
Slump (cm.)	5	5	6.5	5.5

*The highest compressive strength at the replacement of 60 percent

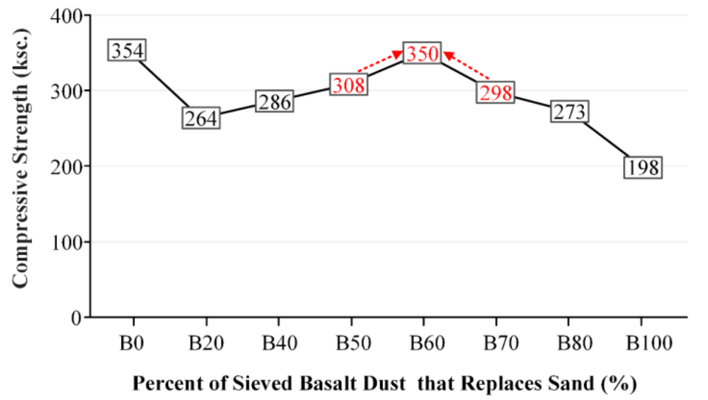

Figure 5 Compressive strength of concrete at w/c = 0.45 on a narrow range to help indicate trend toward the peak strength.

Table 2 Experimental results of the compressive strength and the slump of concrete at w/c = 0.65

Curing(day)	Proportional percentage of sieved basalt dust substituted for sand			
	0	50	60*	70
28	312	208	299	175
Slumping value of the concrete partly composed of sieved basalt dust				
Percent of substitution	0	50	60	70
Slump (cm.)	10	5.5	6.5	5.5

*The highest compressive strength at the replacement of 60 percent

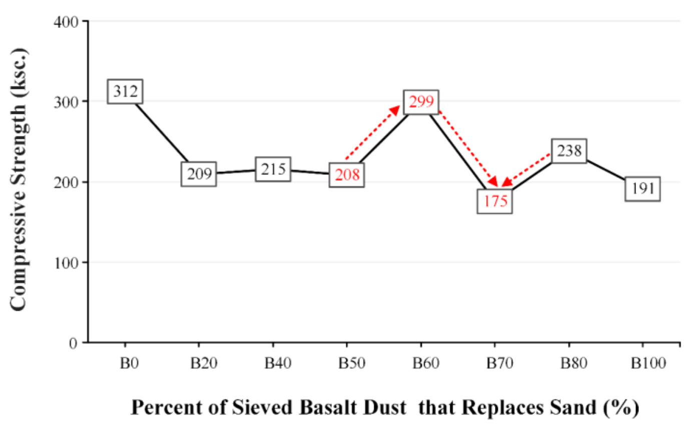

Figure 6 Compressive strength of concrete at w/c = 0.65 on narrower range to help indicate trend toward the peakstrength.

Table 3 Standard deviation (S.D.) of compressive strength of all tested specimens comprised60 – percent sand replacement by sieved basalt dust (w/c = 0.45)

Specimen no.	Test result at 28-day curing (kN)	Kg./sq.cm. (ksc)	$(x_i - \overline{x})^2$
1	616	355.05	27.98
2	612	352.89	9.80
3	594	342.76	49.00
4	612	352.94	10.11
5	598	344.82	24.40
6	607	350.21	0.20
7	606	349.65	0.01
SUM	-	2448.32	121.50
Average	-	349.76	-
Standard deviation (S.D.)			±4.50

Table 4 Standard deviation (S.D.) of the compressive strength of all tested specimens comprised60 – percent sand replacement by sieved basalt dust (w/c = 0.65)

Specimen no.	Test result at 28-day curing (kN)	Kg./sq.cm. (ksc)	$(x_i - \overline{x})^2$
1	499	288.17	121.22
2	509	293.63	30.80
3	515	297.29	3.57
4	501	289.04	102.82
5	520	300.18	1.00
6	547	315.62	270.27
7	538	310.34	124.54
SUM	-	2094.27	654.22
Average	-	299.18	-
Standard deviation (S.D.)			±10.44

Table 5 Standard of the Department of Public Works and Town & City Planning (DPT) 1101-52, specifying the lowest ultimate compressive strength (ksc) for each type of concrete for construction

Type of concrete construction	Lowest ultimate compressive strength of 28-day curing concrete	
	Cubic150×150×150 mm..	Cylinder D150×300 mm..
K1*	190	**150**
K2	210	**180**
K3	240	**210**
K4	280	**240**

* Concrete for general construction

4. Discussion

For additional discussion, the comparison between this research results and the outcomes of previous experiments by other researchers should help clarify the investigation. The former researches concerning the dust aggregate of limestone, granite and basalt dust have shown that the normally mixed concrete provides higher compressive strength. The normal concrete yields about 6% [9] and 18% [10-11] higher strength, compared to the one partly composed of dust aggregate of granite (without sieving) and limestone (sieved). The peak 350 ksc is quite close to the highest outcome 347 ksc of the previous study by Luc Leroy M. N. and associates [12]. Besides, the range of strengths 191 to 350 ksc is slightly different from 173 to 349 ksc, the results of the study by Ukpata O. J. and associates [13]. The granite dust aggregate has its own chemical compositions fairly similar to natural sand, coarser grain and more angular shape [14]. This may be the reason why the difference of compressive strengths is not much, between the concrete normally mixed and the one partly comprising granite dust as sand substitution. Furthermore, the highest compressive strength from this research is about 3% (1.1% - 4.2%) lower than the normal concrete, which provides quite similar strength outcome of granite dust mixed concrete. The dust aggregate of basalt and granite may be reasonably compatible, due to their similar properties as hard igneous rocks: high strength and coarser angular grainsize. However, the use of igneous rocks as aggregates in Portland cement concrete can cause problems. In some instances, fine-grained siliceous materials have caused volume expansion. The alkali - silica reaction problem can be alleviated by adding fly ash (a pozzolan) to the concrete mix. Fly ash, finely ground silica yields a non-expansive reaction product when united with the alkali of the cement paste (CSH, calcium silicate hydrate). The reactive igneous rocks include those that contain volcanic glass with a composition ranging from rhyolite through andesite. Basalt contains too little silica to be reactive [15-16]. The composition of basalt is silica (50% average), alumina (16%), calcium and sodium oxides (13%), iron and magnesium oxides (18%) and countless accessories [16]. The basalt originated at the sea floor often contains chert and jasper (SiO_2) and this make it the most unsuitable composition for concrete aggregate [17]. Therefore, the concrete partly composed of basalt dust may need the detailed investigation of its strength on a long-term basis.

5. Conclusion and Recommendation

The following conclusion is based on the experimental results with some analysis.

5.1 The concrete of both mixing ratios provides the highest compressive strength at 60 percentage of sieved basalt dust in place of sand. The peak strengths that have low variance (standard deviation, S.D.) are 350 ± 4.50 ksc for W/C = 0.45 and 299 ± 10.44 ksc for W/C = 0.65.

5.2 The additional investigation shows that the strength of 350 ± 4.50 ksc.is both more reliable and more consistent.

5.3 The normally mixed concrete has more strengths than the peak strength of the two mixing, yielding 1.1% and 4.2% higher for W/C 0.45 and 0.65 respectively.

5.4 According to the standard DPT1101-52, the concrete with the compressive strength of 350 ksc is able to be applied in practical use for the civil structures that require the concrete type K1 (general civil construction) K2, K3 or K4. Moreover, even the lowest strengths of the concrete partially mixed by sieved basalt dust aggregate as sand substitution are able to be applied in the construction that needs the concrete type K1 or K2.

The further recommendations are below.

1. The basalt dust aggregates are normally site specific. Therefore, the research project to determine the appropriate application in concrete mixing should be under consideration for each area.

2. This research results seem to indicate that the proportion of sieved basalt dust replacing sand has more influence than the water cement ratio, based on the compressive strength of concrete. Consequently, more researches may further clarify this issue.

3. Basalt, a natural product is environmentally friendly with no leaching into ground water, non-toxic, safe to aquatic animals as well as plant-life [18]. Thus, any future research concerning basalt seems promising.

The conclusion above should provide strong confidence that the experimental outcomes are capable of helping to reduce the cost of concrete, to lower the production cost of quarry, to enhance the conservative use of natural resources as well as to mitigate the environmental impact from excavating the sand resources in the nature.

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