THE INFLUENCES OF GRANITE PARTICLE AS A MIXING MATERIAL OF HIGH-STRENGTH CONCRETE

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อิทธิพลของการใช้วัสดุพลอยได้จากการโม่หินแกรนิตในส่วนผสมของคอนกรีตกำลังสูง

น.ส.เมย์ ทาซิน ไคน์

วิทยานิพนธ์นี้เป็นส่วนหนึ่งของการศึกษาตามหลักสูตรปริญญาวิศวกรรมศาสตรมหาบัณฑิต
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เมย์ ทาซิน ไคน์ : อิทธิพลของการใช้วัสดุพลอยได้จากการโม่หินแกรนิตในส่วนผสมของคอนกรีตกำลังสูง. (THE INFLUENCES OF GRANITE PARTICLE AS A MIXING MATERIAL OF HIGH-STRENGTH CONCRETE) อ.ที่ปรึกษาหลัก : เสวกชัย ตั้งอร่ามวงศ์, อ.ที่ปรึกษาร่วม : พิชชา จองวิวัฒสกุล

งานวิจัยนี้มีวัตถุประสงค์ในการศึกษาผลกระทบของการใช้หินแกรนิตต่อสมบัติของคอนกรีตกำลังสูง ซึ่งใช้หินแกรนิตแทนที่ทรายธรรมชาติบางส่วน โดยทำการแบ่งออกเป็นสองกลุ่ม ได้แก่ กลุ่มที่มีสารผสมเพิ่ม และไม่มีสารผสมเพิ่ม สำหรับกลุ่มที่มีสารผสมเพิ่มจะใช้หินแกรนิตแทนที่ทรายธรรมชาติ 0%, 20%, 30%, 40% และ 50% โดยน้ำหนัก และแทนที่ในปริมาณ 0%, 10%, 15% และ 20% โดยน้ำหนัก สำหรับกลุ่มที่ไม่ใส่สารผสมเพิ่ม การทดสอบสมบัติของคอนกรีตประกอบไปด้วย กำลังอัด, กำลังดึงแยก, กำลังดัด, การซึมผ่านของน้ำ และโครงสร้างระดับจุลภาค ยกเว้นกำลังรับแรงดัดผลการทดสอบบ่งชี้ว่าการใช้หินแกรนิตในส่วนผสมส่งผลทางด้านลบต่อสมบัติอื่น ๆ ของคอนกรีตเมื่อไม่ใส่สารผสมเพิ่ม สำหรับกลุ่มที่ใช้สารลดน้ำพิเศษพบว่าการใช้หินแกรนิตเป็นมวลรวมละเอียดในปริมาณร้อยละ 50 ไม่ส่งผลกระทบต่อกำลังอัดและกำลังดัดของคอนกรีต

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May Thazin Khine : THE INFLUENCES OF GRANITE PARTICLE AS A MIXING MATERIAL OF HIGH-STRENGTH CONCRETE . Advisor: Sawekchai Tangaramvong, Ph.D. Co-advisor: Asst. Prof. PITCHA JONGVIVATSAKUL, Ph.D.

The aim of this study is to investigate the effect of granite particle on the properties of high strength concrete by the partial substitution as fine aggregate. By grouping two categories as concrete with and without admixture is also performed in this experiment. The granite particle substitution percentage for concrete with admixture is set with 0%, 20%, 30%, 40% and 50% by weight of fine aggregate and 0%, 10%, 15% and 20% by weight of fine aggregate for concrete without admixture. The testing of concrete strength is conducted with compressive, split tensile, flexural, water permeability, and microstructure. The result shows that the content of granite particle in concrete affects negatively on the properties of concrete without the help of admixture, but except the flexural strength. For the concrete with the combination of superplasticizer, the substitution of granite particle as a fine aggregate can be performed up to 50% without affecting the compressive strength and flexural strength of concrete.

Field of Study:	Civil Engineering	Student's Signature ....
Academic Year:	2018	Advisor's Signature ....
		Co-advisor's Signature ....

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Finally, this journey was filled with a different kind of challenge. However, I could manage to pass those challenges with technical help from my advisor and with mental help from my beloved parents and friends. During studying in Chulalongkorn University, there is a lot of improvement such as logical thinking skill, co-operation skill, and the problem-solving skills which are really helpful not only in my student life but also in my whole career life.

May Thazin Khine

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Chapter 1

Introduction

1.1 Background

Nowadays concrete is widely used as the construction materials in the world. It is proportionally composed of cement, water, fine aggregate and coarse aggregate. Among them, the second most consumptions materials in concrete are fine aggregate and the most commonly used as fine aggregate is the natural sand. Thus, sand is needed to be extracted a lot to supply the required demand from the construction work. Asia is now as the biggest consumer of sand from observations. The demand of sand from the developing country such as Thailand is usually higher than from the developed country for urbanization and economic growth. Now, the production of the sand or importing the sand from the foreign countries are popular to fill such a huge amount of demand and the global resource of the sand is getting less and less.

Since sand is a non-renewable resource, extreme usage of sand brings the negative impact on the environment as the riverbeds and seashore can adversely be damaged by the extracting process. In order to prevent an extreme usage of the non-renewable resource, sand, some researchers are trying to find many ways to approach. Among them, the partial substitution of industrial waste materials in a place of fine aggregate can be one of the possible solutions as there are many kinds of the industrial waste materials extremely produced in different fields and which also negatively impact on the environment without recycling these waste materials.

On the other hand, Granite stone is also widely used in construction. In order to use it in the building process, granite stone is needed to be cut to get the desired shape and size. From the cutting process, a lot of granite particle, exposed as waste material, is being obtained per day. That huge amount of obtained waste granite particle is collected at the landfill area and the amount of collected granite particle is getting increased and shown in Figure 1.1 which is from Chonburi province. As a result, large amount of collected granite waste particle brings the negative effect for environment. Especially, there is a high potential to become air and water pollution. The local residents can also suffer from the lung diseases by breathing the air which is spread with granite dust. Therefore, many researchers have been trying to get way how can the waste material be replaced back in the construction field.

Figure 1.1 Aerial image of granite particle wastes at a landfill site

To cut down these problems, usage of the granite waste materials as recyclable materials in construction can be the effective way as the granite particles are contained the different small particle size that can reduce the size of pores in concrete and increase the compressive strength of concrete. In addition to, the surface texture of granite particles is rougher than the natural sand, therefore it enhances the flexural strength. Due to these properties, granite waste materials are become famous to recycle as fine aggregate in concrete. Hence, the influence of granite particle which is from Thailand on the mechanical properties of concrete is conducted in this study.

1.2 Significant and Innovation

This study will be effective in defending the effects of overwhelming usage of natural sand by reutilization of waste materials such as granite particles as a partial replacement of natural sand in the construction field. By this way, the unnecessary cost for maintaining the waste materials can be significantly reduced. Moreover, the problem related to the environment effect and human health problem can be solved.

1.3 Objective

The main objectives of this research are as follow.

1.1. Investigation of maximum possible substitution percentage of granite particle in the place of sand for the construction field to balance the natural resource consumption.

1.2. Investigate the influence of granite particle on the mechanical properties of high strength concrete with admixture and without admixture.

1.4 Scope of work

The aim of the research is to develop the concrete mix design including with percent of granite waste materials replaced as sand and compare with conventional concrete.

1. Ordinary Portland Cement Type I is considered in this research.
2. Water cement ratio is fixed as 0.4.
3. Granite particle is replaced with 10%, 15% and 20% by weight of natural sand in concrete without admixture.
4. Superplasticizer Type F is applied to improve the workability.
5. Granite particle are utilized as natural sand with 20%, 30%, 40% and 50% by weight of natural sand in concrete with admixture.
6. The cylinder size of 150mm x 300mm is prepared to test compressive strength and splitting tensile strength.
7. The beam size of 500mm x 100mm x 100mm is used to test flexural strength.
8. The cube size of 150mm x 150mmx 150mm is for water permeability testing.
9. Compressive strength, splitting tensile strength, flexural strength and water permeability of concrete are tested at both 7 and 28 days.

1.5 Research Plan

Task	2018											
	1	2	3	4	5	6	7	8	9	10	11	12
Review Literatures												
Define Scope and Methodology of work												
Proposal defense												
Test Sieve Analysis and Physical Properties												
Prepare concrete samples												
Testing properties of concrete												
Preparation of publication and thesis												
Thesis defense												

Chapter 2

Literature Review

2.1 Granite Particle

Granite is a coarse-grained, light-colored igneous rock composed mainly of feldspars and quartz. Granite particle is mainly manufactured from the process of cutting granite stone in a construction work and a lot of ton of granite particle is being obtained from that cutting process per day. The particle has irregular in size and rough surface texture. The water absorption of granite particle is higher than the natural sand. Moreover, the chemical composition of granite particle is shown in Table 2.1 [1].

Table 2.1 Chemical composition of GCW

SiO_2	Al_2O_3	MgO	Na_2O	K_2O
72.57	15.63	0.83	4.21	6.76

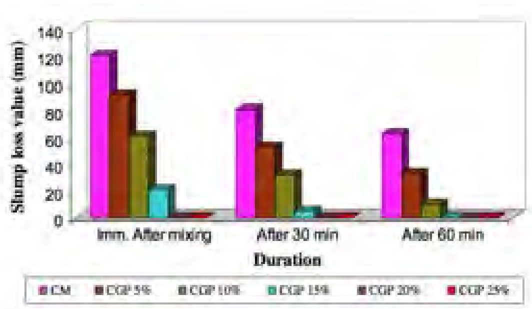
2.2 Superplasticzer

Superplasticizer is the high-range water-reducing admixture (HRWA) which is widely used to reduce the amount of mixing water and cement content required in producing of concrete with high slump (good workability) and increase the strength of concrete. According to ASTM C494, Type F of superplasticizers gives high strength within normal setting times [2].

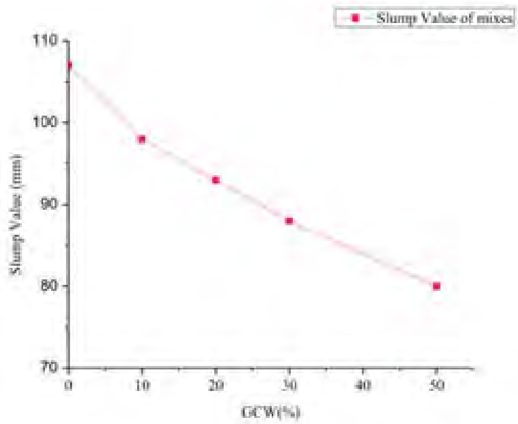
In 2015, Salahadein investigated the influence of superplasticizer dosage cement on the physical properties of fresh and hardened concrete. The test result showed that the workability of concrete was increased effectively by adding the superplasticizer. Moreover, the compressive strength of concrete was improved by the effect of superplasticizer. However, the dosage beyond the optimum limit had led to affect the cohesiveness of concrete [3].

2.3 Granite Particle in concrete

In this section, the study of the granite particle which is used as replacement of fine aggregate in concrete by many researchers is represented in two groups: (1) concrete with admixture and (2) concrete without admixture. In substitution of natural sand by granite particle, most of the researchers observed that the workability of concrete is decreased with increasing amount of substitution percentage at both the condition of concrete with admixture and without admixture shown in Figure 2.1.



(a)



(b)

Figure 2.1 Slump value of different concrete mix (a) without admixture [4] and (b) with admixture [5]

2.4 Effect of granite particle on the mechanical properties concrete with admixture

Sarbjeet Singh (2016) investigated the effect of granite cutting waste as a partial replacement of natural sand in concrete. The percentage replacement made were 10%, 20%, 30% and 50%. It was found the increased percentage of replacement with lower slump values in concrete as rough and angular morphological characteristics of GCW. The maximum percentage replacement of GCW was 30% in the compressive strength test. 50% substitution rate of concrete was comparable with control concrete. In flexural strength, it was increased with increased percentage replacement of granite due to binding action of concrete. The depth of water penetration was gradually decreased with increased substitution rate up to 30% [5]. Kanmalai Williams (2008) observed the performance of concrete made with granite powder. The replacement percentage was set with 0%, 20%, 50%, 75% and 100%. Moreover, the cement was replaced with 7.5% silica fume, 10% fly ash, 10% slag and 1% superplasticizer. The maximum compressive strength and tensile strength were obtained by the concrete specimens with 25% replacement of fine aggregate by granite powder. However, all five concrete mixes of water permeability and drying shrinkage results were similar [6].

A. Arivumangai and T. Felixkala (2014) examined the influence of granite powder on the M30 grade concrete. The granite powder was substituted by 25% and 50% weight of fine aggregate and the cement was also replaced with some admixture namely silica fume, fly ash, slag and superplasticizer. The test result showed that GP25 of compressive strength was slightly higher than that of GP0. However, the splitting tensile strength slightly decreased with increase of granite particle in the concrete [7].

In (2015), Raghavendra R proposed the producing of M40 grade concrete using granite powder as fine aggregate according to 5%, 10%, 15% 20% and 25%. Also, the admixture including fly ash, GGBS, superplasticizer and silica fumes were added. The workability of concrete decreased, while the replacement percentage increased. Moreover, the author observed that the compressive strength of concrete with 15%

replacement percentage was maximum, while 20% and 25% were the comparable granite concrete with standard convectional concrete [8].

Ghannam (2016) evaluated the properties of concrete made with granite powder as sand varied with 5%, 10%, 15% and 20% at 0.4 w/c. For admixture, water-reducing superplasticizer was usage as 0.5% by weight of cement. The result showed that the optimum increments in compressive and flexural strength were found at 10% of sand replaced by granite. And the maximum splitting tensile strength was achieved at 15% replacement of granite powder [9].

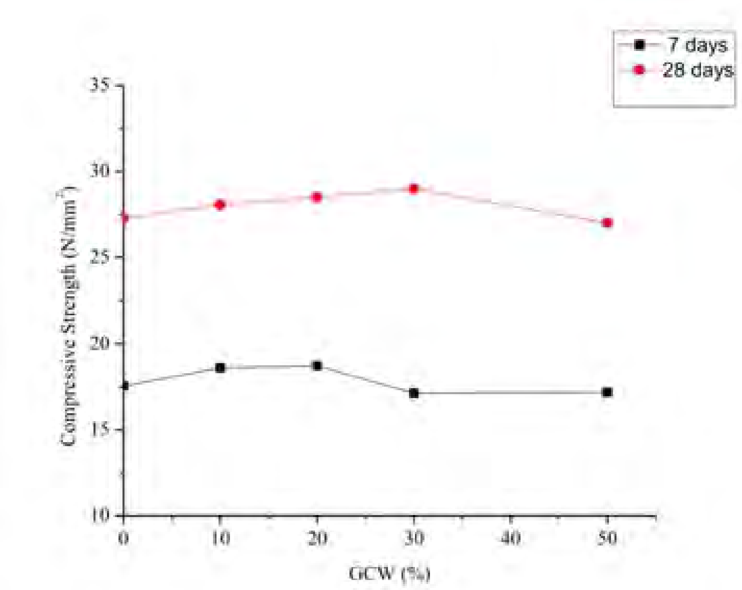


Figure 2.2 Variation of Compressive Strength with Concrete Mix [5]

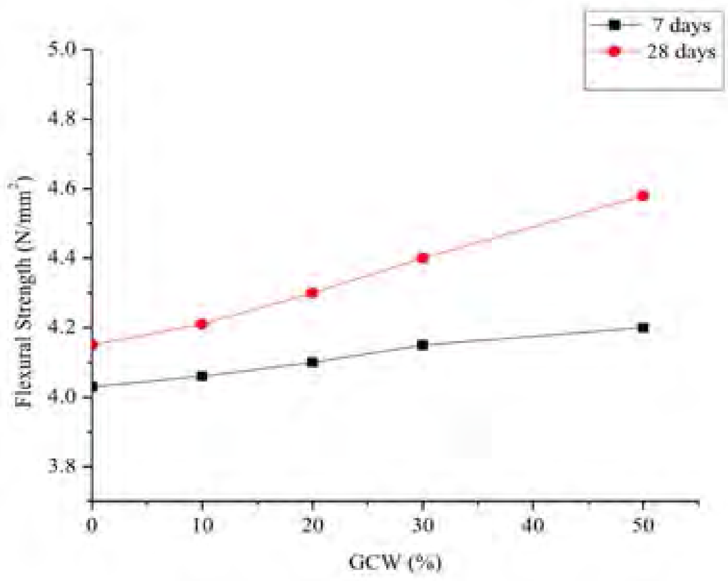


Figure 2.3 Variation of Split Tensile Strength with Days of Curing [5]

2.5. Effect of granite particle on the mechanical properties of concrete without admixture

M. Vijayalakshmi (2013) carried out influence of granite industry waste as a partial replacement of fine aggregate as (0%, 5%, 10%, 15%, 20% and 25%) on the high strength concrete. The compressive strength of the mixture with the replacement up to 15% was observed with better result than control concrete. However, the values of the splitting tensile strength and flexural strength was not achieved effectively by replacing the granite waste as sand [4].

Manasseh JOEL (2010) examined that suitability of crushed granite fine as sand in concrete production. From the experimental result, the replacement of CGF as 20% showed the peak values of compressive strength and indirect tensile strength at 28 days. Moreover, the complete replacement (100%) was successfully comparable with control and recommended from the view of economical [10].

J.Jayavardhan.Bhandari (2015) studied the characteristics of the concrete with the dosage of granite fines. In this paper, the author substituted the granite fines with different percent namely 0%, 5%, 10%, 15% and 20%. Some conclusions also stated that compressive, tensile and flexural strength of normal strength concrete (0.55w/c) was gradually improved by substitution the granite fines up to 15% at all testing ages [11].

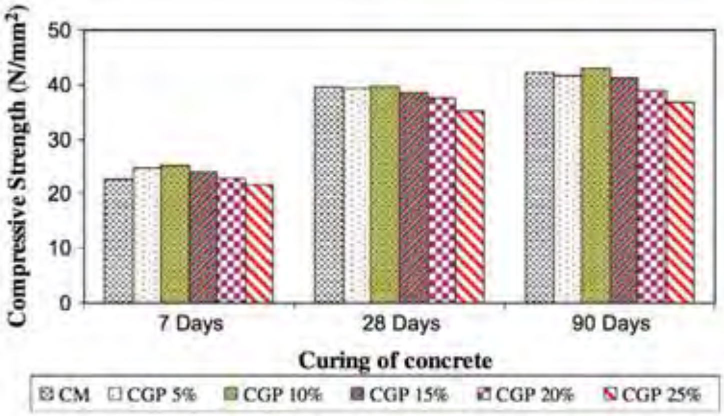


Figure 2.4 Compressive strength of concrete mixture at different ages-comparison [4]

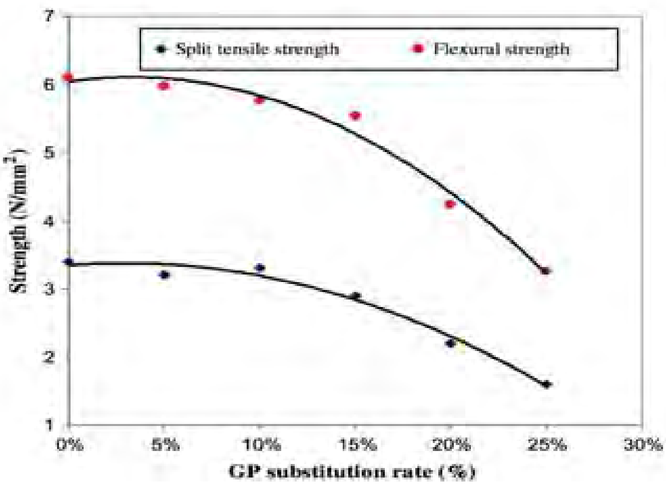


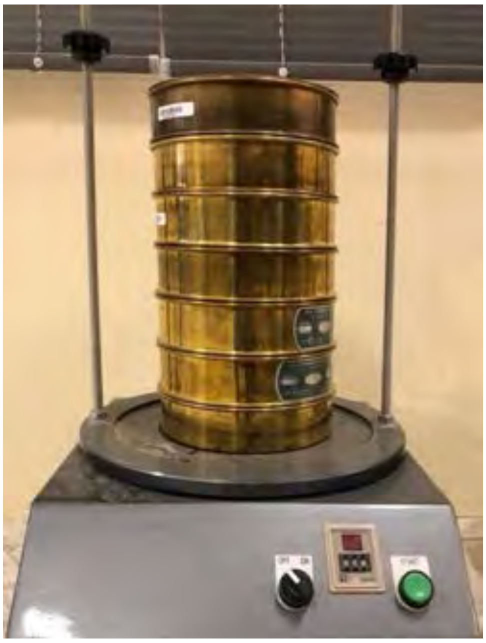
Figure 2.5 Splitting tensile strength and Flexural Strength with different GP substitution rate [4]

Chapter 3
Methodology

In this chapter, the necessary steps and testing methods for research are described as follows.

3.1 Sieve Analysis

Sieve analysis is applied to perform the Grading of aggregates which gives the different particle size of aggregates. The process was performed with mechanical sieve shaker shown in Figure 3.1. After shaking the material in sieve shaker, the percent of materials retained on each sieve was weighed. Then the cumulative percent retained of the aggregate was estimated by summing the numbers in the individual percent retained. From that result, total percent passing was obtained by subtracting cumulative percent retained from 100 as per ASTM C136 [12].



(a)

Figure 3.1 Mechanical sieve shaker

Fineness Modulus of aggregate (sand and granite) was also estimated from the sum of the total percent retained on each specified sieve divided by 100. [12].

3.2 Physical Properties of aggregate

Analyzing of physical properties of aggregate which is an essential process in the estimation of concrete mix design was carried out. They are specific gravity, water absorption, and unit weight.

3.2.1 Specific Gravity and Water Absorption (%)

The specific gravity of the aggregates is required in mixture proportioning to establish weight-volume relationships. Water absorption was determined the change in weight of an aggregate due to water absorbed in the pore space within the particles as per ASTM C128 [13] for fine aggregate and ASTM C 127 [14] for coarse aggregate.

3.2.2 Unit weight

Unit weight is the mass of aggregate divided by the volume of the container to yield dry rodded unit weight and was estimated as per ASTM C29 [15].

3.3 Chemical properties of aggregate

Chemical properties of material (granite) test was conducted to learn the composition of material which depends on local rock source and conditions by using X-Ray Fluorescence (XRF).

3.4 Materials

In this research, Portland cement Type I according to ASTM C 150 [16], the granite particle from cutting of granite stone at Chonburi province and type F of superplasticizer (High Range Water Reducing admixture) according to ASTM C 494 [2]were used.

3.5 Mix proportion

Refer to ACI 211, the required mix proportion amount of materials was estimated. Two different categories were prepared as concrete with admixture and concrete without admixture. The water/cement ratio as 0.4 and the maximum size of coarse aggregate as 19mm were fixed in both mix design. In concrete with admixture, superplasticizer was utilized as 0.5% by weight of cement. The details of two different mix proportion are listed in Table 3.1 and Table 3.2.

Table 3.1 Mix proportion (kg/m^3) of concrete mixture with admixture

Mix	GP0	GP20	GP30	GP40	GP50
Water	178	178	178	178	178
Cement	445	445	445	445	445
Coarse Aggregate	1126	1126	1126	1126	1126
Sand	666	532.4	465.9	399.3	332.8
Granite Particle	0	133.1	199.7	266.2	332.8
Superplasticizer	2.2	2.2	2.2	2.2	2.2

Table 3.2 Mix proportion (kg/m^3) of concrete mixture without admixture

Mix	GP0	GP10	GP15	GP20
Water	187	187	187	187
Cement	467.5	467.5	467.5	467.5
Coarse Aggregate	1126	1126	1126	1126
Sand	624	562	530	499
Granite Particle	0	62	94	125

3.6 Mix Procedure

For mixing the materials, the machine mixer shown in Figure.3.2 was used and the procedure of making and curing of concrete was conducted as per ASTM C 192 [17].

Figure 3.2 Concrete mixer machine

3.7 Specimen

The specimens of concrete were prepared based on the different type of testing. The particular size of specimens is shown in Table 3.3.

Table 3.3 Details of concrete specimens

Testing	Dimension of specimens
Compressive Strength	Cylinder: 150mm x 300mm
Splitting Tensile Strength	Cylinder: 150mm x 300mm
Flexural Strength	Beam: 500mm x 100mm x 100mm
Water Permeability	Cube: 150mm x 150mm x 150mm

3.8 Experimental Procedure

The effect of granite particle on concrete is investigated from mechanical properties including, compressive strength, splitting tensile strength, flexural strength and water permeability. Each testing of concrete was performed 3 times after 28 days of curing and then the average value was taken.

3.8.1 Workability

Workability of concrete was tested as a slump test according to (American Standard Testing Method) ASTM C143. The slump cone size of 200mm diameter for base, 100mm diameter for top and 300mm height was used. The concrete was poured into the cone with three layers and rodded with the tamping rod in each layer. Then the cone was removed slowly with the vertical direction and placed near concrete. Slump value of the concrete (mm) was determined as the depth between the top of cone and top surface of concrete [18].

3.8.2 Compressive strength

The compressive strength was measured by pressing cylinder concrete specimens under the compression-testing machine with a maximum capacity of 3000 KN. According to ASTM C39, cylinder concrete molds after removal from moist storage (7 days and 28 days) were applied compressive load continuously till the specimen failed and then recorded the maximum load during the testing. Compressive strength was evaluated by dividing the maximum load applied to the specimen with the average cross-section area [19].

$$\sigma_c = \frac{4P}{\pi d^2} \tag{3.1}$$

σ_c = Ultimate strength (N/mm^2)

P = maximum load (KN)

d = average diameter of cylinder specimen (mm)

Figure 3.3 Compressive strength test machine

3.8.3 Splitting tensile strength

Splitting tensile strength test on a concrete cylinder is an indirect method to determine the tensile strength of concrete but which is very low compared with compressive strength. In testing, a compressive load was applied diametrically and uniformly along with the length of specimens until concrete split into two halves along the vertical plane. The value of splitting tensile strength was estimated as follow ASTM C496 [20].

Figure 3.4 Splitting tensile strength machine

$$T = \frac{2P}{\pi dl} \qquad (3.2)$$

T = Splitting Tensile strength (N/mm^2)

P = maximum applied load (KN)

d = average diameter of cylinder (mm)

l = the average length of the concrete specimen (mm)

3.8.4 Flexural Strength

Flexural strength of concrete is another tensile strength test after splitting tensile strength test. According to ASTM C 78 [21], prism concrete beams were loaded with two points at one-third of length with flexural strength machine as shown in figure 3.5. In flexural testing, the Load cell was placed above the beam and which was connected with a data logger to record the data.

Figure 3.5 Flexural strength test machine with two-point loading

$$f_r = \frac{PL}{bd^2} \tag{3.3}$$

f_r = Flexural strength (N/mm^2)

P = maximum applied load (KN)

b = average width of specimen at the point of fracture (mm)

d = average depth of specimen at the point of fracture (mm)

3.8.5 Water Permeability

Water permeability test of cube concrete is to determine the depth of penetration of water under constant water pressure (0.5 N/mm^2) which is perpendicular to cube concrete mold filling direction shown in Figure 3.6 as per DIN 1048. After the testing period, the depth of water penetration was measured by splitting the specimens under compressive testing machine into two halves.

Figure 3.6 Water Permeability machine

3.8.6 SEM analysis

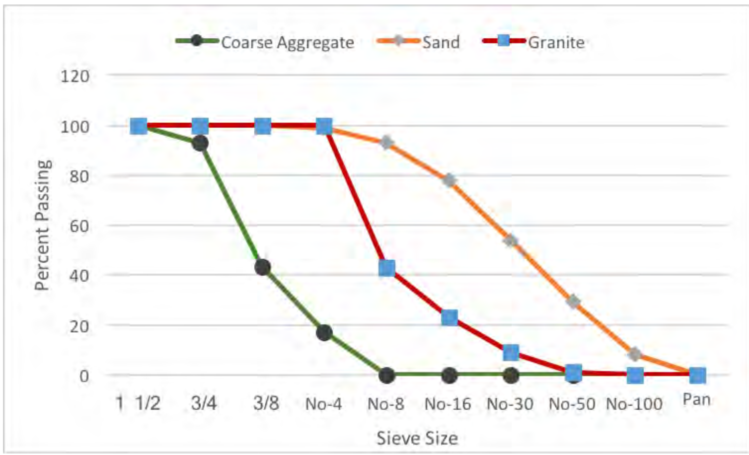
SEM analysis was taken with Scanning Electron Microscope and Energy Dispersive X-Ray machine shown in figure 3.7 (a) to determine the behavior of the concrete specimens such as aggregate particle, cement paste and the interfacial transition zone (ITZ) at micro-structure level. Before the process of scanning images, the small concrete particles were coated with diamond paste (conducting material) to prevent the damages from cutting.

Figure 3.7 Scanning Electron Microscope and Energy Dispersive X-Ray machine

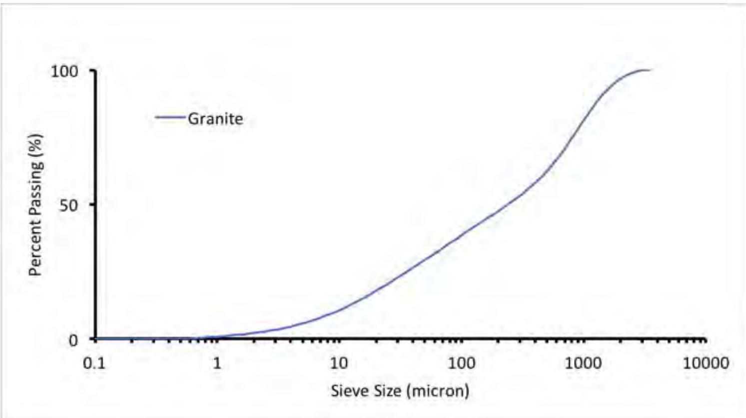
Chapter 4
Results and Discussion

4.1 Sieve Analysis of aggregate

The grading of aggregate (coarse aggregate, natural sand and granite particle) by sieve analysis is shown in Figure 4.1 (a) and the gradation of combined fine aggregate (natural sand + % substitution of granite particle) is shown according to ASTM C33 standard limit in Figure 4.2. The size of granite particle used in this study was ranging from 2.38 mm to finer. Moreover, the particle size distribution of granite particle with microns is also shown in Figure 4.1 (b).



(a)



(b)

Figure 4.1 Particle size distribution of aggregate by (a) sieve analysis method and (b) laser particle size distribution analyser

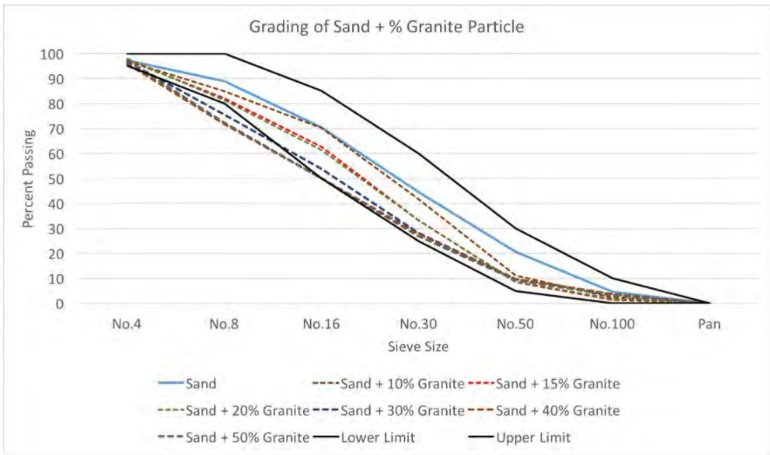


Figure 4.2 Grading of natural sand + % substitution of granite particle according to ASTM C33 limits.

4.2 Physical and Chemical properties of Materials

The general physical properties of fine aggregate (sand and granite particle) are specific gravity, water absorption and unit weight. Each of which detail values are mentioned in Table 4.1. Among them, the water absorption of granite particle is moderately higher than that of sand as the natural sand is homogenous and less porous than the granite particle. From SEM image, the granite particle has an irregular shape and stick with many small particles shown in Figure 4.2. The chemical composition of granite particle is also shown in Table 4.2.

Ordinary Portland cement (Type I) of specific gravity is found 3.51. For coarse aggregate, the specific gravity and fineness modulus are 2.51 and 1.662, respectively.

Table 4.1 Physical properties of granite particle and natural sand

	Granite Particle	Natural Sand
Specific Gravity	2.58	2.61
Water Absorption (%)	0.54	0.24
Fineness Modulus	3.24	2.73
Unit Weight (kg/m^3)	1582.008	1568.387

Table 4.2 Chemical composition of granite particle

SiO_2	Fe_2O_3	Al_2O_3	MgO	Na_2O	K_2O
62	2.77	15.1	1.39	3.03	4.72

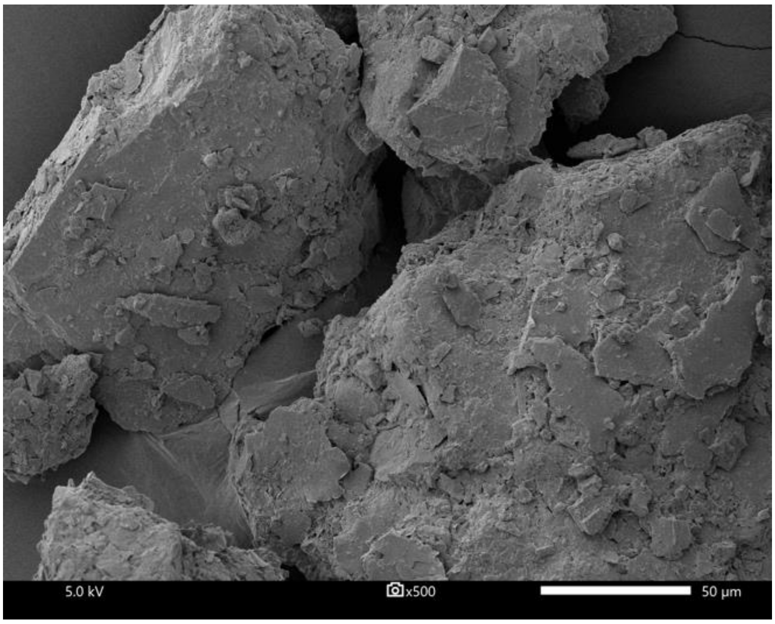


Figure 4.3 SEM image of granite particle

4.3 Concrete without admixture

In this section, the effect of granite particle which was substituted as 10%, 15% and 20% by weight of fine aggregate on the performance of the high-strength concrete (workability, compressive strength, splitting tensile strength and flexural strength) are discussed with the Figures.

4.3.1 Workability

The result from slump test of all concrete mixture is shown in Figure 4.3. It can be observed that all the concrete mixture substituted with the granite particle are loss in workability compared with the control concrete mixture. Also, the higher amount of the granite particle substituted in concrete, the lower the slump value obtained. One reason of loss in workability is due to the development of internal friction between the aggregate which is attributed to the incorporation of granite particle having the irregular shape and rough surface texture. When the substitution of 20% is reached, the slump of concrete is failed with 0 mm.

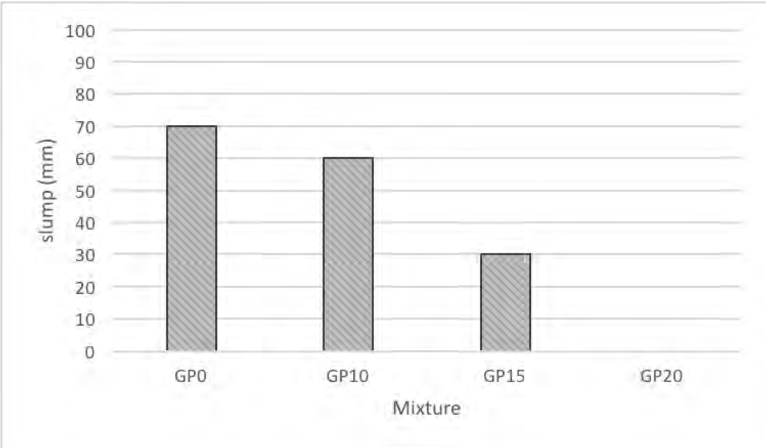
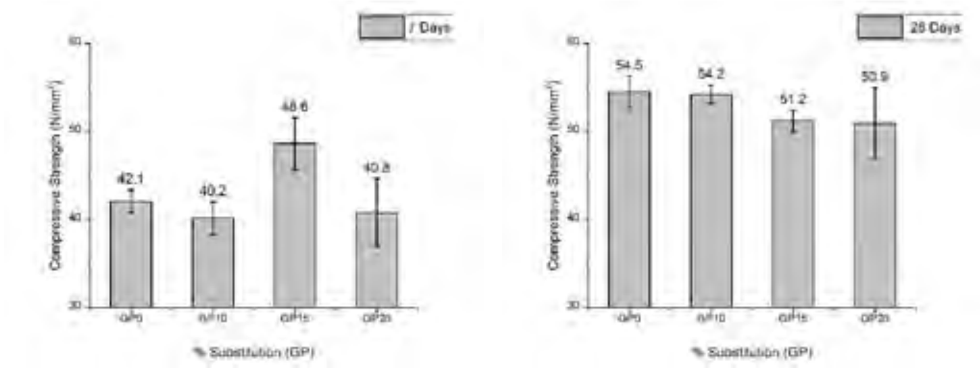


Figure 4.4 Slump values of different concrete mixes

4.3.2 Compressive strength

The experimental compressive strength result of concrete substituted by granite particle vs control concrete after 7, 28 days are shown in Figure 4.4. In the comparison of 7day result and 28day result, the trend of strength development is not similar. At the early age result, the strength development of GP 15 is higher than other strength development. This circumstance can be attributed to the acceleration of granite filler (pozzolans material) on the cement hydration at the early age. After 28 days, there is a gradual decline in the compressive strength with increasing the substitution percentage of granite particle as the concrete where had the poor workability affect the compactness of concrete and thus resulting in the high porosity in concrete.

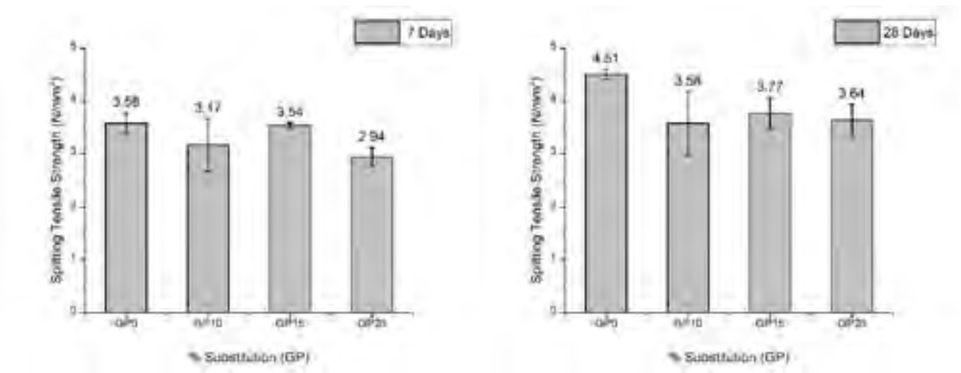


(a) (b)

Figure 4.5 Compressive strength of concrete with different percentage of granite particle (a) 7 days and (b) 28 days

4.3.3 Splitting Tensile strength

The 7 and 28 day results of splitting tensile strength are plotted in Figure 4.5. It is clearly observed that the pattern of strength variation at 7 day is different from that of 28 day. Moreover, there is the large increment in the splitting tensile strength of concrete prepared with granite particle at early age and which is nearly equal with strength values of later age. At 28 days, the strength values of concrete mixtures GP10, GP15 and GP20 are significantly lower than the concrete without the replacement of the granite particle. The reason for the decreased strength obtained in these concrete mixture is that have the poor workability and thus led to affect the binding action between the aggregate and cement paste [4]. Thus, the replacement of granite particle in concrete without admixture does not bring the good result in splitting tensile strength.

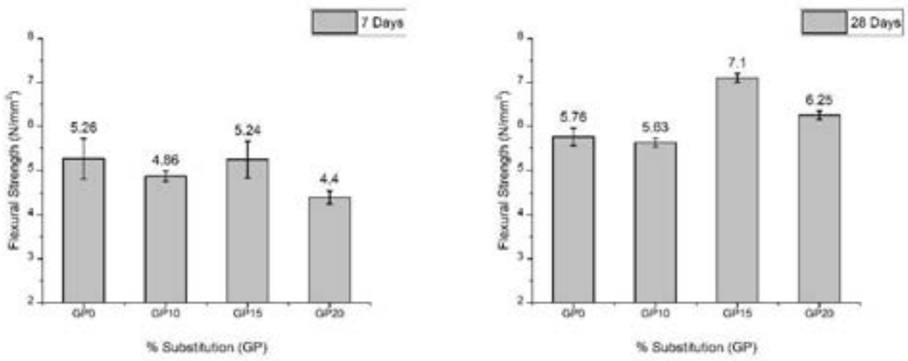


(a) (b)

Figure 4.6 Splitting tensile strength of concrete with different percentage of granite particle (a) 7 days and (b) 28 days

4.3.4 Flexural strength

The flexural strength results of the different concrete mixture are exhibited in Figure 4.6. The flexural strength of concrete was measured after 7 and 28 days of curing. In the 28day result, the strength difference between GP0 and GP10 is not significantly observed. The concrete mixture where 15% of granite particle was replaced as a fine aggregate obtains the maximum flexural strength among other concrete mixture. This can be attributed to the rough surface texture of granite particle which promotes an adhesion between the aggregate and the cement paste. When the granite particle was substituted 20% by weight of fine aggregate in the concrete, the flexural strength is slightly lower than the strength of 15% substitution but is higher than the strength of 0% and 10% substitution.



(a) (b)

Figure 4.7 Flexural strength of concrete with different percentage of granite particle (a) 7 days and (b) 28 days

4.4 Concrete with admixture

In this part, the influence of granite particle on the properties of concrete including workability, compressive strength, splitting tensile strength, flexural strength, water permeability and SEM analysis by adding the admixture is presented with the experimental results. Through the use of Type F superplasticizer, the substitution percentage was set with 20%, 30%, 40% and 50% natural sand replaced by granite particle.

4.4.1 Workability

The workability of different concrete mixture by adding the superplasticizer is shown in Figure 4.7. Generally, the slump value of all the concrete mixes making with granite particle are lower than that of the normal concrete mix. Figure 4.7 shows that the slump value of concrete is decreased starting from GP20 to GP40. The reason of the slump reduced in the concrete mixture is that the internal friction between coarse aggregate and cement paste was increased by adding granite particle which surface texture is not as smooth as the natural fine aggregate.

Once the 50% substitution of granite particle is reached, the slump value is increased back. The amount of water demand in GP50 mix is lower than in GP40 which can be attributed that the particle packing density in concrete was increased by fixing the voids between the particles with huge amount of small granite particle [22].

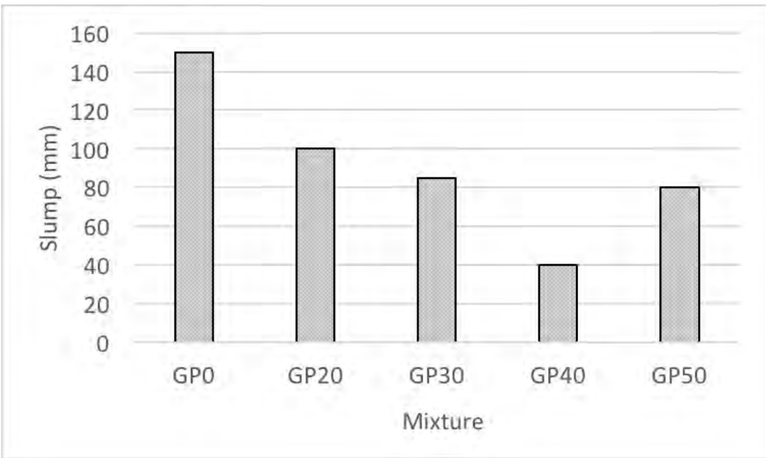
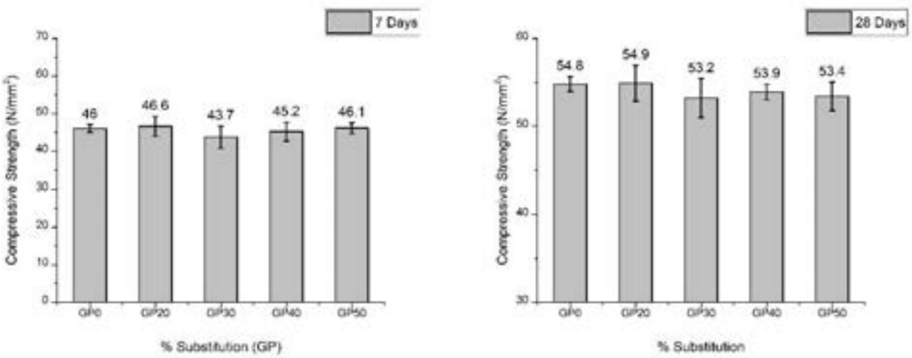


Figure 4.8 Slump of different concrete mixes without admixture

4.4.2 Compressive strength

The variations of compressive strength of the concrete mixture preparing with the granite particle vs conventional concrete at both 7 and 28 day are presented in Figure 4.8. The compressive strength result of 7 day and 28 day is observed with the similar pattern. As seen in this Figure, the effect of granite particle which was substituted up to 50% as fine aggregate in the concrete does not make difference in the compressive strength and thus the concrete mixture of GP20, GP30, GP40 and GP50 are comparable with GP0. This is probably due to increase the surface area of aggregate by substitution of granite particle in concrete, resulting the number of micro voids was increased but, the extra amount of cement can be produced by the ultra-filler in combination with (superplasticizer) to bind the additional surface area [23]. Therefore, the strength of all new concrete are comparable with the traditional concrete.

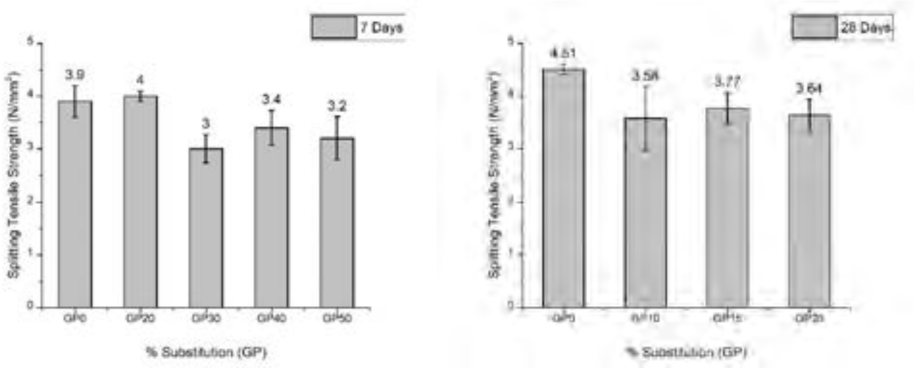


(a) (b)

Figure 4.9 Compressive strength of concrete with different percentage of granite particle (a) 7 day and (b) 28 day

4.4.3 Splitting Tensile strength

The experimental result of splitting tensile strength of concrete substituted with different percentage of granite particle are plotted in Figure 4.9. It can be observed that the 28 days splitting tensile strength is decreased with increasing the granite particle content amount beyond the 20% of granite particle content. The splitting tensile strength did not affect negatively in the GP20 concrete as the bond strength of concrete was improved by rough surface texture of granite particle. Later, the splitting tensile strength value is gradually decreased by increasing from 30% to 50%. This is probably due to these facts that the water demand in concrete and the surface area of fine aggregate was increased by the granite particle content, therefore, that led to affect the interlocking between the aggregate and cement paste [4]. Thus, the replacement of sand by the high amount of granite particle can be affect on the splitting tensile strength.

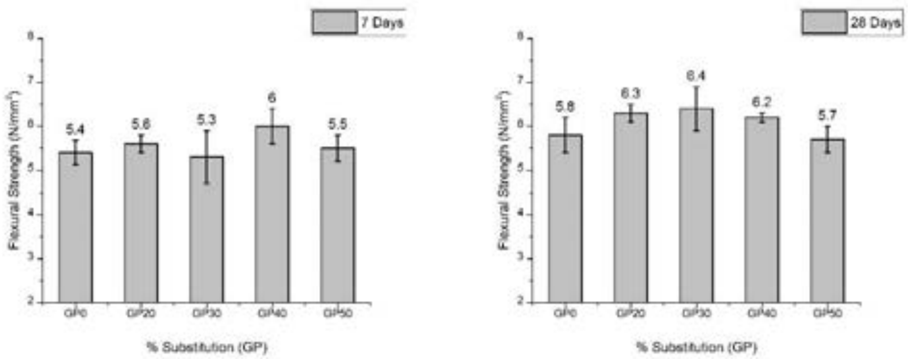


(a) (b)

Figure 4.10 Splitting tensile strength of concrete with different percentage of granite particle (a) 7 days and (b) 28 days

4.4.4 Flexural strength

The flexural strength values of high strength concrete containing the granite particle as 0%, 20%, 30%, 40% and 50% are shown in Figure 4.10. From the Figure, all the strength of concrete substituted with granite particle are greater or comparable to the conventional concrete after 28 days. To be specific, the concrete mixture up to 30% substitution of granite particle the strength is slightly increased and maximum. As mentioned in the section of concrete without admixture, the rough surface texture of granite particle improved the binding action between the aggregate and cement paste and resulting into an increase in the flexural strength. After that the flexural strength is gradually decreased due to the increased surface area of fine aggregate. The flexural strength of GP 50 concrete (with 50% granite particle) is lower than that of (GP30) but comparable with the control mix.



(a) (b)

Figure 4.11 Flexural strength of concrete with different percentage of granite particle (a) 7 days and (b) 28 days

4.4.5 Water Permeability

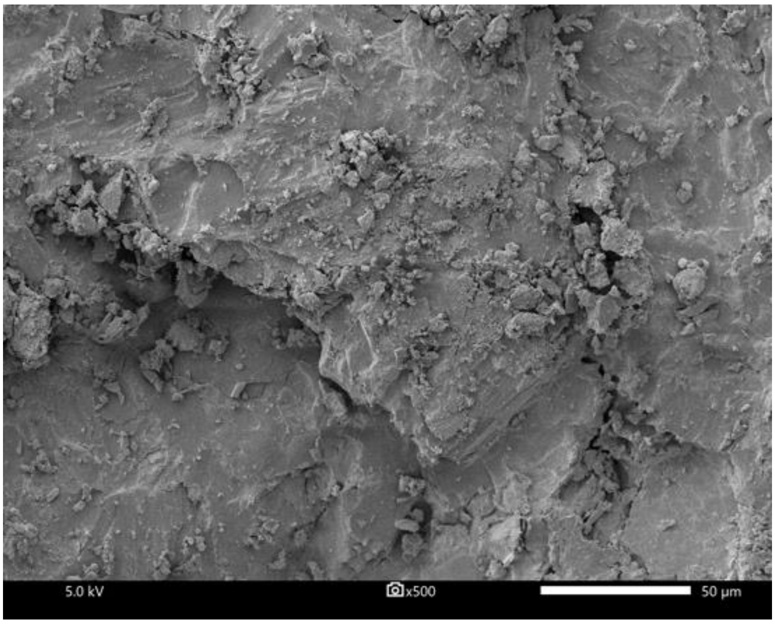
A comparison of water permeability of concrete containing the 20% of granite particle and control mix is shown in Table 4.3. From the result, the water depth of GP20 concrete is higher than normal concrete. The increased in water permeability depth is attributed to the dense graded of fine aggregate by granite particle substituted.

Table 4.3 Water Permeability of concrete with 0% and 20% of GP

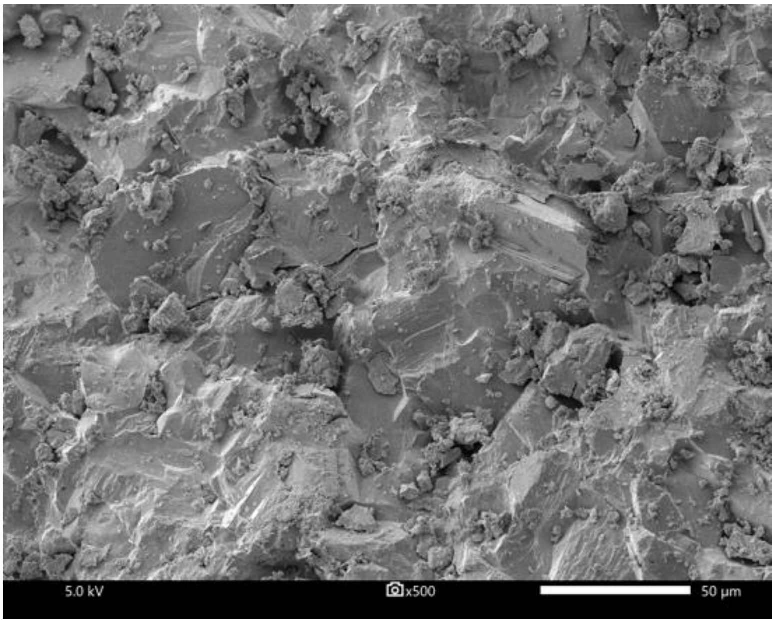
Mix	Water Depth (mm)
GP0	1.56
GP20	2.64

4.4.6 SEM image

Figure 4.11 illustrates the scanning electron microscope analysis of concrete containing the granite particle as 20%, 30%, 40% and 50%. It can be observed that the higher the substitution percent of granite particle, the looser the cement paste. Moreover, the number of micro cracks are getting more and more while comparing with the traditional concrete. Therefore, the replacement of granite particle in concrete is not achieved the good compactness in the cement paste.



(a)



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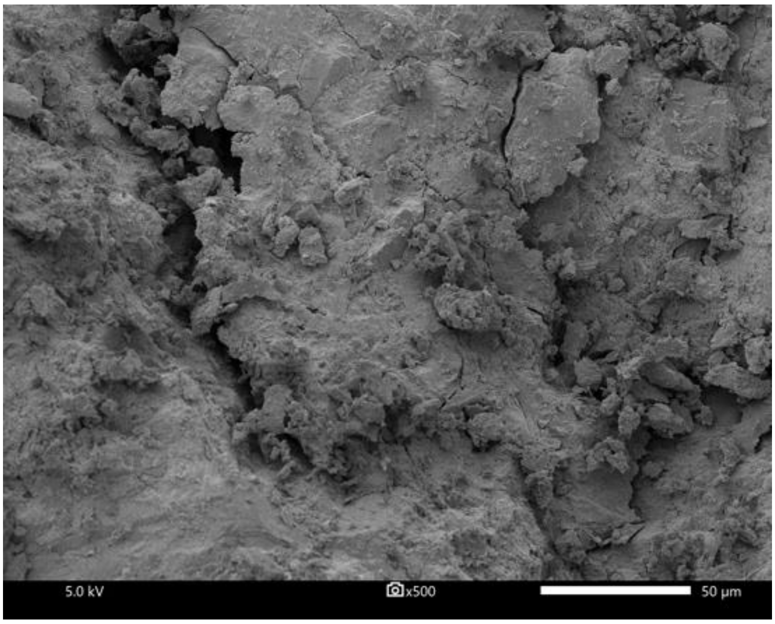
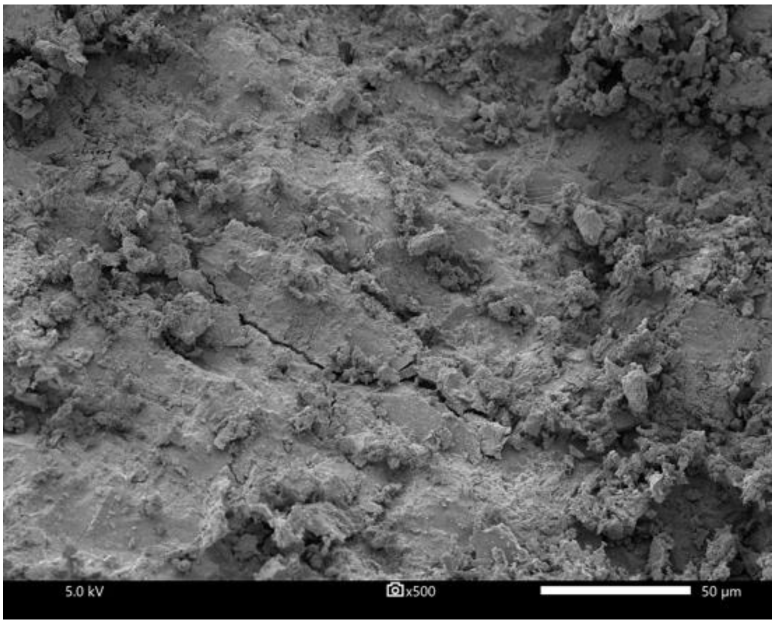
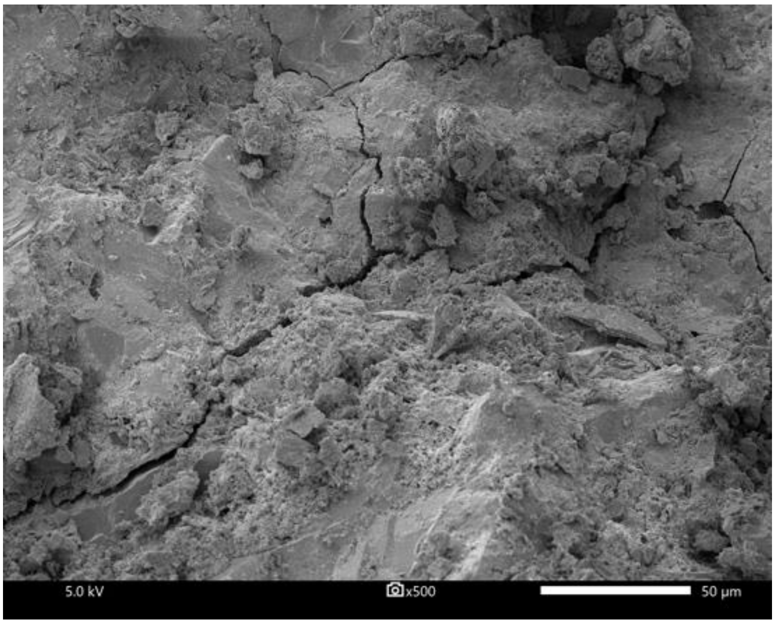


(c)



(d)



(e)

Figure 4.12 SEM image of Concrete mixes (a) 0%, (b) 20%, (c) 30%, (d) 40% and (e) 50%

Chapter 5
Conclusions

In this thesis, the feasibility of usage of granite particle in the dry condition as a partial substitution of fine aggregate in concrete is studied. Practically, the properties of fresh and hardened concrete mostly depend on the aggregate shape, size and surface texture. Thus, the following conclusions can be drawn.

1. Partially substitution of granite particle in concrete production without admixture, the following observations are found.
    a. The workability of concrete can be decreased by the substitution of granite particle.
    b. Due to poor workability, the concrete substituted with granite particle can obtain the decreased values in compressive and splitting tensile strength.
    c. Flexural strength of the concrete mixtures can be increased by the roughness texture of granite particle.
2. In the concrete with the combination of admixture, granite particle affect on the properties of concrete as followings.
    a. The slump value can be decreased with the increasing substitution percent of granite particle whereas on GP50, the slump value is slightly increased back and higher than GP40 due to the effective particle packing density.
    b. Granite particle can be replaced as natural sand up to 50% in the concrete with the comparable compressive strength to the control concrete.
    c. The concrete mixture substituted with 20% of granite particle can obtain the comparable splitting tensile strength.
    d. Substitution of 30% granite particle results in the optimal flexural strength and the concrete substituted up to 50% granite particle can be comparable to that of control concrete.
    e. Inclusion granite particle in the concrete can increase the water permeability depth of concrete.

f. SEM image analysis confirms that the incorporation of granite particle leads to less compact in the cement-aggregate matrix.

5.1 Recommendation

Based on the experience from investigation the effect of granite particle as fine aggregate in concrete, the following recommendations and additional testing for future research are found

1. Adjusting the surface moisture of granite particle to reach the saturated-surface dry condition before substitution as fine aggregate.
2. Analyzing the internal expansion in concrete after the reaction of fine aggregate (granite particle) in the alkaline environment with alkali aggregate reactivity (AAR) testing.

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REFERENCES

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