The Substitution of Fine Aggregate with Interlocking Material of Stone Quarry Dust in High Strength Concrete

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Abstract. Some of the parameters for improving the quality of concrete are the selection of its constituent materials and compaction process to increase the interlocking between materials. The selection of cubical aggregate as fine aggregate in the form of stone dust origin from quarry stone residue was chosen as a research object as it is suspected can increase the interlocking material due to its sharp edge. This study aimed to improve the interlocking between material in concrete so as to improve the compressive strength of high strength concrete. The research method is using the standard in SNI 03-6468-2000 (Pd T-18-1999-03) with water cement ratio of 0.3 and 25-50 mm planned slump. Sica viscrocrete – 10 and silica fume was added as additive. The percentage of sica viscrocrete – 10 and silica fume respectively is 1.5% and 10% from cement weight. Dust is used as the substitution of fine aggregate. Compressive strength test in this study was performed using 30 cm height and 15 cm width concrete cylinder specimen at 7 and 28 days old. From the test, it was obtained that the compressive strength at 7 days is 53.14 MPa for concrete using natural sand and 52.04 Mpa for concrete using stone dust and at 28 days old is 68.19 MPa for concrete using natural sand and 82.52 MPa for concrete using stone dust. It can be concluded that stone dust as fine aggregate substitution can boost more compressive strength of high strength concrete as it has a cubical and sharp plane edge which can help to increase the interlocking between material during the compressive strength test.

Keywords: Quality improvement, high strength concrete, compressive strength test

1. Introduction

High strength concrete is one of concrete types which has high compressive strength. Generally, its required compressive strength is greater than 41.4 MPa [1]. Most of the concrete constituent material is aggregate which tied with cement paste. The commonly used aggregate is come from nature, for example river stone and sand. Natural aggregate caused the presence of porosity which is becoming one of the most influential problems of compressive strength in high quality concrete. The use of natural river sand and uniform granule size which has round form can provide airspace in concrete which result in smaller compressive strength.

Meanwhile, angular aggregate particles with the sharp corner can resist the possibility of aggregate movements during compressive strength test. This is because it has more than one split plane that will give more extra bonds between concrete constituent, reduce the percentage of porosity in concrete and increase its workability.

Crushed stone dust is chosen as natural fine aggregate replacement because its cubical form is suspected can provide better interlocking between material. Concrete with better material interlock will
increase its strength. The aim of the study is to determine the compressive strength of high strength concrete at 7 days and 28 days old using crushed stone dust as natural fine aggregate replacement. This research was performed at Construction and Building Materials Laboratory Civil engineering Department Universitas Muhammadiyah Aceh. Mix design method was using standard in SNI 03-6468-2000 (Pd T-18-1999-03) with water cement ratio of 0.30 and slump of 25-50 mm. Concrete cylinder of 15 cm diameter and 30 cm height was used as specimen.

2. High Strength Concrete
High strength concrete can be interpreted as a high performance concrete that takes into account the durability as well as workability of concrete. In high strength concrete, the decreasing of particle and pore size will increase the material strength [2]. Generally high strength concrete has a required strength of 40–80 MPa, and nowadays increasing accordance to its application.

High strength concrete has been used widely in high rise structure as column, beam and foundations. It is also used for bridges structures and highway pavement. Its application in structures reduces the dimension of structural element so the dead load also reduces. The characteristic of high strength concrete is its high early strength, high modulus elasticity, durability and compaction without segregation [3].

3. Aggregate
Aggregate is one of the important ingredients in concrete, which occupies 70% -75% of the concrete volume, so that the aggregate is very influential on the properties of concrete [4]. Once the aggregate is used according to the requirements then the concrete may have good workability, strong, durable and economical value. In the use as concrete material, aggregate is divided into 2 i.e fine aggregate and coarse aggregate, which is usually, comes from the river.

The shape of aggregate may affect the workability of the concrete mix during the mixing period in terms of the compacting energy required for the mixture to be set and the strength of structural concrete during its service life [5]. Moreover, the strength of the aggregate will also affect the compressive strength of the concrete. Main factors affecting concrete strength are aggregate interlocking and porosity [5]. Aggregate with good gradation and sharp edge is more likely to have better interlocking.

Stone dust is a side product of a quarry which has a sharp corner. It is resulted from the process of breaking stone into pieces which has a granular size of 0 - 5 mm and shaped like a pebble but has a smaller diameter which is less than 5mm [6]. It is produced from the location of the stone crusher contain approximately 17% to 25% dust fraction [6]. Therefore, stone dust has a potential volume to be used in other purpose for example to replace the use of fine aggregate from the river.

4. Compressive Strength
Compressive strength of concrete is obtained using a test machine, by providing a multilevel press load with a certain incremental load speed on the cylindrical test object until it crushed [7]. Generally, the testing procedures is using ASTM C39-86 standard. The compressive strength is measured using standard cylinder specimen of 150 mm diameter and 300 mm height at 28 days old.

The compressive strength of each specimen is determined by the compressive stress (fc') achieved at the 28-day test due to the experimental load. Based on the collapsed loads that can be accepted by the specimen, the value of the compressive strength of the structural concrete can be calculated using equation (1) below.

\[ fc' = \frac{P}{A} \]  

Where fc' is the compressive stress (MPa), P is the load (N), and A is the cross sectional area (mm²).
5. **Research Methodology**

Method used in this research is according to [8]. This procedure applies only for high strength concrete produced using conventional materials and production methods. The research process was performed according to the figure 1 below.

![Figure 1. Research Procedure](image)

Variation and the number of specimen can be seen in table 1. The use of water in high strength concrete is very little which results on mortar that is difficult to work with. A high level of workability for mortar will be obtained by adding superplastizer to achieve the appropriate slump value without bleeding and segregation. In this study, Sika Visocrete 10 was chosen as an additive. It was added in the same amount for each variation which was 1.5%.
Table 1. Variation and Number of Specimen

| Variation of Fine Aggregate | Days | Number | Note   |
|----------------------------|------|--------|--------|
| Dust 100% + 1,5% Sika Viscocrete + 10% Silica Fume | 7 28 | 10 10 20 |        |
| Pasir 100% + 1,5% Sika Viscocrete + 10% Silica Fume |       | 10 10 20 | comparison |
| Total Number | | 40 |        |

6. Results and Discussion

Based on the result of mix design in the form of water, cement, fine sand, coarse sand, dust and additive material (silica fume deni sika viscocrete-10) using SNI 03-6468-2000 method (Pd T-18-1999-03) are summarized in table 2 in the form of a proportion of concrete mixtures for each variation per 1 m³

Table 2 Proportion of Concrete Mixture for each variation per 1 m³

| Material type | Material Weigh(kg) |
|---------------|--------------------|
|               | Stone Dust 100%    | Sand 100% |
| Water         | 159                | 167       |
| Cement        | 521                | 548       |
| Split         | 1144               | 1144      |
| Stone Dust    | 574                | -         |
| Sand          | -                  | 553       |
| Silica Fume   | 52,1               | 57        |
| Sika Visocrete| 7,8                | 8,5       |

From the calculation of the proportion of concrete mixture, it can be seen the use of cement in concrete mixture using stone dust is less compared to the one that used natural river sand. This is because in the aggregate physical properties of the two types of aggregates are obtained different bulk density which affect the required water content.

From the slump test, it is obtained average slump of 19 – 21 cm, which meets the required slump of 25 -50 cm. Slump test is shown in table 3 below.

Table 3. Slump Test

| No | Variasi Pengujian | Slump (cm) |
|----|-------------------|------------|
|    |                   | 10 specimens | 10 Specimens | Rata-rata |
| 1  | Stone Dust 100%   | 19          | 21           | 20         |
| 2  | Sand 100%         | 21          | 21           | 21         |

The high slump value that can be seen in the table above due to the addition of superplasticizer to obtain high workability in concrete specimen.

From the test results and data processing performed statistically, concrete compressive strength values obtained at 7 days and 28 days old concrete specimen are shown in table 4.
Table 4. Test Result and Data Processing

| Specimens Variation | Life Factor (day) | Fine Aggregate | Average \( f'_c \) (MPa) | Sd | \( f'_c \) (corrected)(MPa) |
|---------------------|-------------------|----------------|-----------------|----|----------------|----------------|----------------|----------------|
| 7                   | Pasir (100 %)     | 52.13          | 3.68            |    | 47.2           | 57.05           | 53.14          |
| 7                   | Dust (100 %)      | 52.07          | 2.5             |    | 48.72          | 55.42           | 52.04          |
| 28                  | Pasir (100 %)     | 66.69          | 5               |    | 59.99          | 73.39           | 68.19          |
| 28                  | Dust (100 %)      | 83.94          | 6.27            |    | 75.55          | 92.34           | 82.52          |

The ratio of compressive strength of concrete of stone dust and natural sand mixture at 7 days and 28 days old test is shown in bar chart at figure 2. The result shows that concrete mixture using stone dust as fine aggregate, the compressive strength corrected at 28 days old reach 82.53 Mpa. It is found that with the substitution of stone dust as fine aggregate can boost the compressive strength of high strength concrete. Moreover the obtained compressive strength suit the minimal compressive strength of high strength concrete requirement in SNI 03-6468-2000 (Pd T-18-1999-03) which is 41.4 MPa. The compressive strength of concrete using stone dust is increasing 50.1% from the design.

Figure 2. Comparison Graph of Compressive Strength for each Variation

7. Conclusion
Based on the result, it can be concluded that the use of quarry stone dust as fine aggregate substitution can increase the compressive strength of high strength concrete. It is proven that stone dust granule which has angular aggregate particle with sharp corner gives better aggregate interlocking which can prevent the possibility of aggregate movement in the concrete with its higher result of compressive strength. Moreover, higher compressive strength at the earlier age of concrete reaches 52.04 Mpa which is more than the required strength, confirm the theory that high strength concrete has an high early strength.
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