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Characteristic of stress-strain on SCC incorporating with HVFA under uniaxial compression

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Abstract. Self-compacting concrete (SCC) is a very special concrete that have inherent characteristics like a flowability, self compactability, segregation resistance and improved performance. The objective of this study is to investigate the effect of specimen size on the stress strain of SCC incorporating with High Volume Fly Ash (HVFA) compared to normal concrete for different sizes of height to diameter (h/d) ratio, with the fixed diameter (d) cylinder parameter. The experimental results show that the magnitude of stresses HVFA-SCC concrete and normal concrete will decrease on higher specimen size. The maximum strain and ductility factor of HVFA-SCC concrete is greater than normal concrete.

1. Introduction
High-volume fly ash (HVFA) concrete represents a promising solution for the construction industry to deal with the issues related to the global emissions of greenhouse gases [1]. Under the Kyoto Protocol, efforts to reduce or slow down emissions of greenhouse gases such as carbon dioxide (CO2) have been carried out by developed countries. With such public concerns, the concrete industry and the construction sector are trying to focus on reducing cement production in the manufacture of concrete in two main directions [2]. Self compacting concrete (SCC) can be considered as concrete that can be poured and placed in the desired location and can condense under its own weight, with little or no vibration, without bleeding or segregation. This property is very useful for facilitating and ensuring proper handling and better structural performance in narrow areas and strengthening of structural elements. This offers important advantages in recent years [3]. Significantly, the compressive strength of concrete can be influenced by several factors. These factors are specimen size factor, specimen aspect ratio because aggregate is not scaled, friction differences occur on concrete surfaces with loading plates, varying crack propagation and localization of failure zones [4]. The behavior of complete stress-strain is a basic of concrete which is the principle parameter in the analysis and design that needs to be developed on concrete structural elements [5]. To support the uses as a structural element of this type of concrete, a reliable stress-strain relationship must be determined carefully [6]. It has been shown by previous researchers [7] that the complete stress-strain characteristic of the concrete on uniaxial compressive loading is affected by the type of concrete being investigated. This study will investigate the behavior of stress-strain HVFA-SCC concrete with 50% fly ash compared to normal concrete on cylindrical specimens at different sizes of height to diameter (h/d) ratio, on the fixed diameter (d) cylinder parameter. In addition, other parameters used were the same compressive
strength design at 28 days of age for HVFA-SCC concrete and normal concrete, which was 35 MPa, on d = 7.5 cm and h = 7.5 cm of cylindrical specimens.

2. Experimental Methods

2.1. Material Properties
The coarse aggregates used were from Kulonprogo, Yogyakarta and the fine aggregate was taken from Bekonang, Sukoharjo. For specific gravity tests on coarse aggregates follow ASTM C127 and for specific gravity test on fine aggregate adjusted to ASTM C128. Gradation of the coarse aggregates and fine aggregates were determined according to ASTM C136. Coarse aggregate has an apparent specific gravity of 2.725 and fineness modulus was 5.687. While fine aggregate has a value of apparent specific gravity of 2.703 and fineness modulus was 2.981. The type of cement used is the Ordinary Portland Cement (OPC) type that conforms with ASTM C150. In order for the concrete mixture to be flowing, it was used superplasticizer (SP) with chemical base of modified polycarboxylate copolymers. It is particularly developed for the production of high flow concrete with exceptional flow retention properties and significant reduction in segregation and bleeding. Fly ash taken from Jepara power plant. Based on the results of chemical content test, fly ash is included type C. In Table 1, described the chemical content of fly-ash.

Table 1. Fly-ash chemical composition

| Compound       | %   |
|----------------|-----|
| Al₂O₃          | 10.06 |
| Fe₂O₃          | 17.60 |
| SiO₂           | 30.29 |
| CaO            | 34.49 |
| TiO₂           | 1.20  |
| MnO            | 0.11  |
| K₂O            | 2.09  |
| SO₃            | 2.76  |
| P₂O₅           | 0.53  |

The composition of SCC is in accordance with EFNARCH 2002. For the composition of SCC incorporating with fly ash 50% content is presented in Table 2. And the composition of normal concrete is presented in Table 3.

Table 2. Composition of HVFA 50%-SCC

| Fly Ash (kg/m³) | Cement (kg/m³) | Coarse Agregat (kg/m³) | Fine Agregat (kg/m³) | Water (lt/m³) | SP (lt/m³) |
|-----------------|----------------|------------------------|----------------------|--------------|------------|
| 384.3           | 384.3          | 709.8                  | 595.35               | 231          | 7.68       |

Table 3. Composition of normal concrete

| Cement (kg/m³) | Coarse Agregat (kg/m³) | Fine Agregat (kg/m³) | Water (lt/m³) |
|----------------|------------------------|----------------------|---------------|
| 750            | 782.42                 | 566.58               | 225           |

2.2. Specimen Test
In this experiment there are three cylinder size groups, each with a ratio of height of cylinder (h) to diameter (d) being h/d=1, h/d=1.33 and h/d=2. The diameter of the fixed cylinder was 7.5 cm with variations on the cylinder height of 7.5 cm, 10 cm and 15 cm. Each group consists of 3 specimens. The concrete used were HVFA-SCC concrete with 50% fly ash and normal concrete. The total number of specimens were 18 pieces. The concrete specimen were cured under wet burlap for 21 days and then stored in the laboratory for 7 days. Then at the age of 28 days, the specimens are tested under uniaxial compression test. During the test, there was no reduction of friction between loading of the platens and specimens. A complete stress-strain diagram was determined using data of global longitudinal deformations, measured by the embedded transducer of the UTM. To control the deformation occurring in the specimen, the strain rate in the Universal Testing Machine (UTM) device was set at 1.5 mm/min. The following in Figure 1-2, shows the specimen fracture mode.
Figure 1. Lateral strain gauge on surface of specimen

Figure 2. Fracture mode of cylinder specimen

3. Results and Discussion

Based on experimental test results, the following is presented diagram of stress-strain curve for HVFA-SCC concrete with fly ash 50%.

Figure 3. Experimental stress-strain curve on cylinder size of 7.5x7.5 cm (a). Experimental stress-strain curve on cylinder size of 7.5x10 cm (b).

Figure 4. Experimental stress-strain curve on cylinder size of 7.5x15 cm (c). Average stress-strain experimental curve of HVFA-SCC (d).

Based on Figures 3 and 4, can be determined of the maximum stress ($f'c$), peak strain ($ԑ_p$) and maximum strain ($ԑ_{max}$) on HVFA-SCC at 28 days of age. In Table 4, the value is presented.
Table 4. The value of parameter stress-strain HVFA-SCC

| Parameters                  | Heigth of HVFA-SCC cylinder specimen (cm) |
|-----------------------------|-------------------------------------------|
|                             | 7.5 cm | 10 cm | 15 cm |
| Maximum stress ($f'_c$) (MPa) | 33.24  | 27.00 | 25.69 |
| Peak strain ($\varepsilon_0$) | 0.0027 | 0.0026 | 0.0025 |
| Maximum strain ($\varepsilon_{max}$) | 0.0069 | 0.0073 | 0.0060 |
| Ductility factor            | 6.83   | 4.07  | 5.78  |

As for normal concrete (NC), based on experimental test results for cylindrical specimens at 28 days of age, the following stress-strain curve diagrams are obtained.

![Figure 5](image1.png)

**Figure 5.** Experimental stress-strain curve on cylinder size of 7.5x7.5 cm (a) Experimental stress-strain curve on cylinder size of 7.5x10 cm (b).

![Figure 6](image2.png)

**Figure 6.** Experimental stress-strain curve on cylinder size of 7.5x15 cm (c). Average stress-strain experimental curve of normal concrete (d).

Based on Figures 5 and 6, can be determined of the maximum stress ($f'_c$), peak strain ($\varepsilon_0$) and maximum strain ($\varepsilon_{max}$) on normal concrete (NC) at 28 days of age. In Table 5, the value is presented.

Table 5. The value of parameter stress-strain normal concrete (NC)

| Parameters                  | Heigth of NC cylinder specimen (cm) |
|-----------------------------|-------------------------------------|
|                             | 7.5 cm | 10 cm | 15 cm |
| Maximum stress ($f'_c$) (MPa) | 35.96  | 35.83 | 35.38 |
| Peak strain ($\varepsilon_0$) | 0.0024 | 0.0024 | 0.0023 |
| Maximum strain ($\varepsilon_{max}$) | 0.0046 | 0.0041 | 0.0045 |
| Ductility factor            | 5.39   | 3.83  | 3.65  |
Based on the experimental results data above, in Figure 7 presented a diagram between the maximum stresses on HVFA-SCC 50% fly ash concrete specimens compared to normal concrete (NC).

![Chart showing stress comparison](chart.png)

**Figure 7.** Maximum stress HVFA-SCC 50% and normal concrete (NC)

According to Figure 7, the magnitude of stresses occurring in HVFA-SCC concrete and normal concrete will decrease in higher test specimen size (h). This is consistent with that proposed by Mindess 2002, which states that the increasing size of the specimen causes the decrease of the compressive strength value and raises the variation in the value of the test result. On the Figure 8 shows the magnitude of HVFA-SCC strain compared to the normal concrete strain.

![Chart showing strain comparison](chart8.png)

**Figure 8.** Maximum strain HVFA-SCC 50% and normal concrete

In Figure 8, it appears that the maximum strain occurring in HVFA-SCC concrete was greater than the maximum strain on normal concrete. This suggests that strain-softening areas in HVFA-SCC are longer than normal concrete. The longer the strain that occurs, the ductility tends to increase. The ductility factor ($\mu$) is the ratio between the ultimate deformation and the elastic deformation (after 0.4 $f'_c$) as shown in the following equation:

$$\mu = \frac{\delta_u}{\delta_y}$$  \hspace{1cm} (1)

*note:*

$\mu$ = ductility factor  
$\delta_u$ = maximum strain at rupture  
$\delta_y$ = strain at post elastic (at 0.4 $f'_c$)
Based on stress-strain diagram above, can also be determined value of ductility factor of concrete. This concrete ductility factor is the ability of the concrete to deform due to loading before it rupture. To calculate the ductility factor, there are several methods. In this research, the ductility factor was calculated as the ratio between the total area under the complete stress-strain curve to the total area up to 40% of peak stress. Figure 9 shows the value of ductility factor of HVFA-SCC concrete compared with normal concrete.

![Ductility Factor Diagram](image)

**Figure 9.** Ductility factor diagram of HVFA-SCC 50% compared normal concrete

Figure 9 shows that HVFA-SCC concrete has greater ductility factor than normal concrete.

4. Conclusions
Based on the experimental results it can be concluded that the magnitude of stresses HVFA-SCC concrete and normal concrete will decrease on higher specimen size. The maximum strain and ductility factor of HVFA-SCC concrete is greater than normal concrete.

5. References

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