Silicon Powder and Ash Concrete Dynamic Performance

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Abstract. Through SHPB dynamic impact test, the dosage of silicon powder and fly ash in the concrete was researched, then the paper studied silicon powder and fly ash content on the effect of dynamic mechanical properties of concrete. The results showed that: Influence the dynamic compressive strength is FJSG, FJGS, FGJS, with the increase of the strain rate, that is the increase of the impact speed, the influence on the dynamic compressive strength of the concrete by the silicon powder also increases

Experimental Program and Specimen Making

Experiment Materials

The experiment uses the common P·O52.5 concrete produced by the Huaihai Zhonglian concrete L.T.D. in XuZhou, the sand is the common river sand, the aggregate meets the continuous grading demand that the maximum particle diameter is 20mm. Water is the drinking water in XuZhou, water reducing agent is the efficient MN water reducing agent produced by the YunLong concrete additive plant in XuZhou, the water reducing rate is 15%-25%. The silicon powder is the TOPKEN920U tiny silicon powder produced by the Tiankai silicon powder materials L.T.D. in Shanghai. The ash is from heat-engine plant in XuZhou, the loss on ignition is 5%, the fineness is 17, the density is 2.35g/cm³, belongs to II ash.

The paper considers four factors and three standards, which is water binder ratio, silicon powder, the dosage of the ash, sand coarse aggregate ratio. Conduct a design on the orthogonal test of mixing silicon powder and ash, for comparison, the paper also design the comparison experiment on mixing silicon powder, ash only.

Dynamic Impact Test

The incident bar is straight cone variable cross-section bar, its minimum diameter is 37mm, maximum diameter is 74mm. The paper conduct the experiment on 19 groups of test-pieces with different mix proportion, for concrete with ash only, we use 0.2MPa, 0.3MPa, 0.5MPa three pressure to do the impact test, for concrete with silicon powder only, we conduct 0.2MPa, 0.4MPa, 0.6MPa three pressure to do the impact test on the concrete with silicon powder and ash.

Optimization Analysis of Orthogonal Factors

We conduct the impact test under three pressure of the concrete with both ash and silicon powder under 0.2,0.3,0.6MPa, then get the stress-strain curve of the concrete as shown in Figure 1,2,3. It can be draw that: with the increase of the experimental strain rate, the failure stress in the test-pieces also increase. The strain rate of the concrete is under the range of 87-175s⁻¹, for concrete with silicon powder and ash, the dosage of group O-6 is best, the top stress of the concrete under 0.6MPa improved 27.1% compared with plain concrete.

We can draw the conclusion from the range analysis in Table 1, under the low , intermediate and high strain rate, the primary and secondary factors that influence the dynamic compressive strength is FJSG,FJGS,FGJS, with the increase of the strain rate, that is the increase of the impact speed, the influence on the dynamic compressive strength of the concrete by the silicon powder also increases, it increase to rank 2 under the high strain rate from the last place in the four factors under the low
strain rate, the adulteration of silicon powder have an important effect on the shock resistance, especially under the high-speed impact.

Table 1. Range calculation results of the each factor of dynamic compressive strength of concrete under the effect of different air pressures’ impact.

| Level | 0.2MPa | 0.4MPa | 0.6MPa |
|-------|--------|--------|--------|
|       | J      | G      | F      | S      | J      | G      | F      | S      | J      | G      | F      | S      |
| 1     | 56.8   | 60.3   | 58     | 126.1  | 123.5  | 138.5  | 126.7  | 178.3  | 166.9  | 187.3  | 174.5  |
| 2     | 62.3   | 54.8   | 59.8   | 133.8  | 128.3  | 120.8  | 127    | 174.3  | 175.1  | 164    | 171.1  |
| 3     | 60.3   | 58     | 61.5   | 119.5  | 127.6  | 120.1  | 125.7  | 168.1  | 178.7  | 169.4  | 175.1  |
| Range | 5.5    | 2.63   | 11.7   | 3.5    | 14.3   | 4.86   | 18.34  | 1.03   | 10.2   | 11.8   | 23.3   |

Figure 1. Stress-strain curve of the group O test-pieces under 0.2MPa.

Figure 2. Stress-strain curve of the group O test-pieces under 0.4MPa.

Figure 3. Stress-strain curve of the group O under 0.6MPa.

Figure 4. Influence of orthogonal factors on test-pieces dynamic compressive strength.

With the impact speed and the strain rate increasing, its influence is more obvious.

Let analyze the experimental dynamic compressive strength value of the same factor under different standards, the experiment designs four factors and three standards, from figure 4 we can see that under low impact speed: when the water binder ratio is 0.3, the dynamic compressive strength reaches the maximum value, so the dynamic compressive strength reaches the maximum value when we use J2, the compressive strength reaches the maximum value when the sand coarse aggregate ratio is G3, the compressive strength reaches the maximum value when the fly ash use the
10% dosage, the sand coarse aggregate ratio is 38%, that the best group under low speed impact is J\(_2\)G\(_3\)F\(_1\)S\(_3\); the best group under immediate speed impact is J\(_1\)G\(_1\)F\(_1\)S\(_3\); the best group under high speed impact is J\(_1\)G\(_3\)F\(_1\)S\(_3\). From the data in figure 1-3, we can see the compressive strength of the J\(_2\)G\(_3\)F\(_1\)S\(_2\) that is group O-6 is best, this is in consistence with the four factors that have influence on the dynamic shock resistance. Sum up the above analysis, silicon powder can obviously improve the dynamic shock resistance of concrete, at the same time, with the improvement of the strain rate, silicon powder have a more obvious influence on the concrete.

**Dynamic Growth Factor**

The ratio between material dynamics and static strength is Dynamic Increase Factor, referred to DIF. Most of the research now think that there exists functional relations between DIF and the logarithm of strain, concrete under uniaxial compressive stress state, the relationship between DIF and strain rate suggested by European Concrete Committee (CEB) is:

\[
DIF = \frac{f_c}{f_{cs}} = \begin{cases} \left(\frac{\dot{\varepsilon}}{\varepsilon_s}\right)^{0.26 a_s}, & \dot{\varepsilon} \leq 30/s \\ \gamma_s (\dot{\varepsilon}/\dot{\varepsilon}_s)^{0.3}, & \dot{\varepsilon} > 30/s \end{cases}
\]

(1)

The coefficient \(a_s, \gamma_s\) is:

\[
\begin{align*}
\alpha &= \frac{1}{5+9(f_c/f_{cs})}, & f_{cs} = 10\text{MPa} \\
\lg\gamma_s &= 6.15\alpha_s - 2
\end{align*}
\]

(2)

Among it, \(f_c\) is dynamic compressive strength and \(f_{cs}\) is static compressive strength, \(\dot{\varepsilon}\) is dynamic experimental strain rate and \(\dot{\varepsilon}_s\) is static experimental strain rate.

In the research on the strength and the strain rate relationship of the concrete, people care more about the increase in dynamic compressive strength under the differential strain rate compared with static compressive strength, that is the relationship between dynamic increase factor and the strain rate. For the DIF of the same series but different strain rate, static strength is the same constant value, so the DIF of high strain rate can be expressed as the form of power function of the strain rate. Next, for quasi static and dynamic experiment, under the small range of the strain rate, compressive strength increases faster, if use the power function to reflect the relationship between them. Sum up the above two aspects, we use relation similar to CEB to analyze the relationship between DIF and strain rate of concrete. In the equation, \(\alpha, \beta\) is boundary strain rate of the fitting parameters K.

\[
DIF = \frac{f_c}{f_{cs}} = \begin{cases} \left(\frac{\dot{\varepsilon}}{\dot{\varepsilon}_s}\right)^{\alpha}, & \dot{\varepsilon} \leq \kappa \\ \gamma_s \left(\frac{\dot{\varepsilon}}{\dot{\varepsilon}_s}\right)^{\beta}, & \dot{\varepsilon} \geq \kappa \end{cases}
\]

(3)

Take the concrete with silicon powder only for example, to fit it, the value of K is determined by the experiment that it is far greater than its general value 20, choose the second formula to fit, and get the result by using the Origin software:

\[
DIF = \frac{f_c}{f_{cs}} = \gamma_s \left(\frac{\dot{\varepsilon}}{\dot{\varepsilon}_s}\right)^{\beta} = 3.0187 \times 10^3 \left(\frac{\dot{\varepsilon}}{\dot{\varepsilon}_s}\right)^{1.3369}
\]

(4)

Then get the corresponding scatter diagram and the fitting curve is shown in figure 5, Y-axis express dynamic factors, X-axis express \(\dot{\varepsilon}/\dot{\varepsilon}_s\). Fitting correlation coefficient R=0.83579, it shows that there exists larger correlation between fitted equation and the practical results, from the scatter diagram and the fitting curve, under the low strain rate, the scatter of dynamic factors is closely
distributed around the fitting curve, deviation from the error is small, but under the immediate strain rate, the scatter of dynamic factors deviate larger from the fitting curve, deviation from the error is larger; under the high strain rate, the scatter of dynamic factors is close to the fitting curve, deviation is larger than the low strain rate but smaller than the immediate strain rate. With the increase of the strain rate, the dynamic factor increases continuously, which is with the increase of the strain rate, the peak value of concrete dynamic damage is also increasing.

![Figure 5. The fitted curve of the DIF and the strain rate.](image)

**Conclusion**

1. Influence the dynamic compressive strength is FJSG, FJGS, FGJS, with the increase of the strain rate, that is the increase of the impact speed, the influence on the dynamic compressive strength of the concrete by the silicon powder also increases.
2. Through the research of dynamic increase factors, the fitted equation had good express.

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