STUDY ON THE PERFORMANCE OF HIGH-POINT THROWING NON-VIBRATION CONCRETE

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Abstract

High-point throwing non-vibration concrete is a kind of concrete adopting high-dropping construction method, being able to fill up the mold and compact uniformly under the effect of kinetic energy and dead-weight. The characteristic of this concrete is that it will get some appropriate properties such as flow-ability, pass-ability and dense compaction after high dropping when being not segregated.

The results of this study are as follows: compared with self-compacting concrete, the workability requirement of high-point throwing non-vibration concrete is lower, but the requirement for anti-segregation is stricter. Properties of concrete mixture in this experiment can satisfy the requirements of high dropping construction. Moreover, this concrete is still able to keep an appropriate flow-ability after high dropping, easily fill up the mold and compact uniformly finally. Strength values of this concrete for cubic samples with 12m height dropping are closed to those of normal SCC, and strength values of core samples are relative stable except 4Sq. These above show that there is no obvious negative influence of high dropping construction method on the workability and strength of the concrete. The result of rebounding test and ultrasonic pulse wave velocity test prove the dense compaction inside the concrete body without defects caused by free vibration.

Keywords: high-point throwing, non-vibration, casting height, strength stability

1. INTRODUCTION

High-point throwing non-vibration concrete is a new type of concrete able to flow flatly inside the mold by kinetic energy and finally fill up it, but also to be well compacted by its dead-weight without any vibration. The characteristics of high-point throwing non-vibration
concrete include the appropriate flow-ability under the condition of high dropping, the fill-ability in the mold without segregation or bleeding, and the homogeneous compaction of the concrete after hardened. This concrete will increase the height of casting for normal self-consolidating concrete and simplify the pumping operation. Moreover, it makes the self-consolidating concrete-filled steel tubular[1,2] successfully applied in constructions, especially for high-rise or super high-rise structures, underground or underwater pipeline projects with a large casting height. Simultaneously this concrete can also apply in some projects with complicated shapes, large pouring volume and buildings not suitable for normal construction[3]. However, there has been no general construction and application specifications for high-point throwing non-vibration concrete. It is a restriction for extensive application of such concrete in building industries. Therefore it is quite necessary to study construction performance and hardened properties of high-point throwing non-vibration concrete on site.

2. EXPERIMENTAL MATERIALS

All the materials for this experiment are offered by Xincai Concrete Mixing Plant of Chongqing Construction Group, and the property indexes are listed as follows.

2.1 Cement

The cement used in this experiment is P.O 42.5 produced by Chongqing Lafarge Factory. The chemical composition and physico-mechanical properties are shown in Table 1 and 2.

Table 1: Chemical composition of binders (%)

<table>
<thead>
<tr>
<th></th>
<th>SiO₂</th>
<th>Al₂O₃</th>
<th>Fe₂O₃</th>
<th>CaO</th>
<th>MgO</th>
<th>TiO₂</th>
<th>SO₃</th>
<th>Loss on ignition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cement</td>
<td>21.21</td>
<td>5.55</td>
<td>3.46</td>
<td>63.68</td>
<td>0.89</td>
<td>0.20</td>
<td>2.91</td>
<td>1.46</td>
</tr>
<tr>
<td>Fly ash</td>
<td>41.26</td>
<td>27.25</td>
<td>14.6</td>
<td>2.83</td>
<td>0.79</td>
<td>1.37</td>
<td>1.17</td>
<td>6.5</td>
</tr>
</tbody>
</table>

Table 2: Physico-mechanical properties of cement

<table>
<thead>
<tr>
<th>Density (g/cm³)</th>
<th>Specific surface area (m²/kg)</th>
<th>Flexural strength (MPa)</th>
<th>Compressive strength (MPa)</th>
<th>Setting time (min)</th>
<th>Soundness</th>
<th>Water demand for normal consistency</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.02</td>
<td>338.5</td>
<td>6.2</td>
<td>8.9</td>
<td>29.1</td>
<td>55.1</td>
<td>152 210 Qualified by boiling test</td>
</tr>
</tbody>
</table>

2.2 Coarse aggregate

Crushed lime stone from Gele Mountain of Chongqing are adopted. The coarse aggregates for this experiment are obtained by combining 5-10mm diameter particles with 10-20mm ones in ratio of 1:1. The bulk density is 1400kg/m³ and 1460kg/m³, respectively. And the mud content is 0.5%.
2.3 Fine aggregate
The sand used for this experiment is a combination of machine-made sand with fineness modulus 3.4 and the super fine sand with fineness modulus 1.4 at the ratio of 5:5. The average fineness modulus of the mixture is 2.4 after blending. The bulk density is 1590kg/m³ and 1490kg/m³, respectively. The mud content is 1.6%, and the stone powder content 4.0%.

2.4 Fly ash
Fly ash of grade II is from Chongqing Luohuang Electric Power plant. The density is 2.25g/cm³ and the specific surface area 278m²/kg. Chemical composition of it is shown in Table 1.

2.5 Water reducer
PDN-OR is adopted in this experiment with a water reduction of 20%.

3. TEST METHOD AND MIX PROPORTION OF THE CONCRETE

3.1 Test of construction properties of the mixture
Two molds are used for this experiment: one is a 6×1×2m cube. Inside, the steel reinforcing bars are arranged with intervals of 20mm, 35mm and 40mm on one side, and the contrary order for the other side. The length of the steel bar is 2m. The casting height for this mold is 8m. The other mold is 0.8×0.8×3m cube with a casting height of 12m.

The properties of fresh concrete on site such as flow-ability, fill-ability, the gap passing-ability and anti-segregation were tested by slump cone, spread board, L- and U-shaped box and stability sieving instruments.

On the other hand, observing the flow distance of fresh concrete under the dropping kinetic energy and the gap passing-ability through steel reinforced bars when high-point throwing non-vibration concrete pouring on site.

3.2 The molding methods of concrete for strength test
We choose 3 molding methods in order to compare effects on the concrete’s strength with normal non-vibration molding method, the laying-off heights of 0.5m and 1m non-vibration molding method, taking samples after being cast at the height of 8m and 12m non-vibration molding method. Then cubes with a dimension of 100×100×100mm were formed and then standard cured (20°C±2°, RH≥95%) in the curing chamber.

At last, the effect of different laying-off heights on strength values was determined by testing 3day-, 7day-, and 28day-compressive strength values.

3.3 Testing method of strength and compaction of hardened concrete
Apart from the normal testing machine, the bouncing device (ZC3-A) and core sampling method were also used to test strength values for the cast concrete on site. Take samples from left to right for No.1 mold, naming them by 1Sq to 3Sq, and up to down for No.2 mold, naming them by 4Sq to 6Sq when core sampling.

In addition, the ultrasonic pulse wave velocity tester was adopted to detect the compaction
of high-point throwing non-vibration concrete.
The molds for casting on site are shown in Fig.1.

![The molds for casting on site](image)

**Fig.1: The molds for casting on site**

### 3.4 Mix proportion for the experiment on site

The final mix proportion for the experiment and another 2 proportions of SCC on site are shown in Table 3. The concrete is transported by 3 concrete mixer trucks.

Table 3: The mix proportion of concrete (kg/m$^3$)

<table>
<thead>
<tr>
<th>Number</th>
<th>W/B</th>
<th>Binders</th>
<th>Sand</th>
<th>Aggregate</th>
<th>Water Reducer (% of binders)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>C</td>
<td>F</td>
<td>S</td>
<td>5~10 mm</td>
</tr>
<tr>
<td>1</td>
<td>0.38</td>
<td>400</td>
<td>50</td>
<td>0</td>
<td>252</td>
</tr>
<tr>
<td>*SL-5</td>
<td>0.38</td>
<td>320</td>
<td>50</td>
<td>80</td>
<td>840</td>
</tr>
<tr>
<td>*SL-12</td>
<td>0.38</td>
<td>310</td>
<td>50</td>
<td>70</td>
<td>840</td>
</tr>
</tbody>
</table>

* *SL-5 and *SL-12, are from ‘The Final Report of Study on Self-compacting Concrete’ (unpublished material by Yang Changhui).

The mix proportion [4, 5] and the test of workability [6, 7] of high-point throwing non-vibration concrete must be determined in the lab before the experiment on site for the mix proportion is crucial for the construction method of a concrete. Then adjust the mix proportion according to the weather and pumping conditions on that day.

### 4. THE RESULT AND ANALYSIS OF EXPERIMENT

#### 4.1 The construction properties of fresh concrete

The performance requirement of high-point throwing non-vibration concrete is different from that of self-compacting concrete. In order to avoid the segregation of this mixture after...
high dropping, the slump and flow spread values may be smaller compared with those of self-compacting concrete. But there is no permission of mortar segregation at the edge of the mixture when testing the concrete for flow spread value.

The test results of workability of concretes from every concrete mixer truck and normal SCC are shown in table 4.

Table 4: Test results of workability of the mixture

<table>
<thead>
<tr>
<th>Number</th>
<th>Slump (mm)</th>
<th>Slump spread (mm)</th>
<th>T\textsubscript{500} (s)</th>
<th>L-box H\textsubscript{2}/H\textsubscript{1}</th>
<th>U-box (h\textsubscript{1}-h\textsubscript{2})\Delta h (mm)</th>
<th>Mass of concrete m\textsubscript{1}(kg)</th>
<th>Mass of mortar m\textsubscript{2}(kg)</th>
<th>Stability sieving (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1-1</td>
<td>265</td>
<td>560</td>
<td>3</td>
<td>0.60</td>
<td>70</td>
<td>15</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1-2</td>
<td>270</td>
<td>575</td>
<td>2.8</td>
<td>0.69</td>
<td>30</td>
<td>4.4</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>1-3</td>
<td>260</td>
<td>557</td>
<td>3</td>
<td>0.55</td>
<td>80</td>
<td>5.0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>*SL-5</td>
<td>280</td>
<td>700</td>
<td>1.57</td>
<td>0.79</td>
<td>-</td>
<td>(Flow table test)f\textsubscript{m}=86%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>*SL-12</td>
<td>275</td>
<td>680</td>
<td>2.25</td>
<td>0.86</td>
<td>-</td>
<td>(Flow table test)f\textsubscript{m}=43%</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-2* 8m</td>
<td>170</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1-3* 12m</td>
<td>230</td>
<td>530</td>
<td>4</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*1-2* 8m’ means concrete from No.2 mixer truck after 8m dropping; and ‘1-3* 12m’ means concrete from No.3 truck with a drop of 12m height.

1. We can draw from the table 4 that compared with *SL-5 and *SL-12, the flow-ability of high-point throwing non-vibration concrete is a little poorer but has the better cohesiveness. Actually it is the most difference for the requirement of construction between these two concretes. Because the shock caused by high dropping of high-point throwing non-vibration concrete will improve the flow-ability and compaction to some extent when concrete being not segregated, which can be proved by ‘1-3* 12m’, still having the slump of 230mm and slump spread of 530mm after 12m height dropping.

2. ‘1-2* 8m’ shows that after 1 hour later, concrete dropped from 8m height had a big loss of slump. It is mostly time-depending loss. So, as for high-point throwing non-vibration concrete, it is still required appropriate construction time which normally not exceeded 30min to obtain the satisfied construction properties.

3. The test result of ‘0’ of sieved mass ratio in Table 4 indicates that it is not suitable for anti-segregation test for this high-point throwing non-vibration concrete by stability sieving method because of the large viscosity it has. We need to find out a better way to test it.

4. Having finished the casting of high-point throwing non-vibration concrete into the
No.1 mold and de-molding, we can find by observing the concrete body surface that the mixture has a homogeneous compaction in the range of 2m radius from the casting point as its center, showing a good gap pass-ability in this scope of the concrete body.

The workability test and flow-ability inside the mold are shown in Fig.2 and Fig.3.

![Fig.2: L- and U-shaped box test](image1.png)  ![Fig.3: The flowing state in the No.1 mold](image2.png)

4.2 Strength values of hardened concrete

4.2.1 Strength of cubic samples

The strength values of cubic samples with different laying-off heights in 3days, 7days and 28days are shown in table 5.

Table 5: strength values of cubes

<table>
<thead>
<tr>
<th>Number</th>
<th>Laying-off</th>
<th>Dropping height</th>
<th>3d-strengh</th>
<th>7d-strength</th>
<th>28d-strength</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>0.5m</td>
<td>0</td>
<td>29.3</td>
<td>35.8</td>
<td>43.0</td>
</tr>
<tr>
<td>2</td>
<td>1m</td>
<td>0</td>
<td>29.2</td>
<td>31.7</td>
<td>40.6</td>
</tr>
<tr>
<td>3</td>
<td>0.5m</td>
<td>8m</td>
<td>28.6</td>
<td>32.3</td>
<td>38</td>
</tr>
<tr>
<td>4</td>
<td>0.5m</td>
<td>12m</td>
<td>32.4</td>
<td>36.4</td>
<td>42.3</td>
</tr>
<tr>
<td>5</td>
<td>1m</td>
<td>12m</td>
<td>32.7</td>
<td>36.8</td>
<td>45.9</td>
</tr>
<tr>
<td>6(*SL-5)</td>
<td>--</td>
<td>--</td>
<td>29.8</td>
<td>39.4</td>
<td>48.5</td>
</tr>
<tr>
<td>7(*SL-12)</td>
<td>--</td>
<td>--</td>
<td>33.4</td>
<td>39.4</td>
<td>46.5</td>
</tr>
</tbody>
</table>

We can find in table 4 that: *SL-5 and *SL-12 have the largest strength values among these groups. As for concretes without dropping, we get the lower strength values with the laying-off height grows, because the height of laying-off may lead to the slight non-uniform inside the concrete body. But for concretes with a drop of 12m height, compared with those without dropping, the strengths seem larger, and also there is no obviously difference between the laying-off height of 0.5m and 1m. It may be caused by the tight compaction after the 12m dropping, and the values are closed to those of 6 and 7 groups, proving that this concrete studied here still has the appropriate mechanical property even after 12m dropping.

Additionally, the 3group has the smallest values in table 4, showing that after 1 hour later,
there is a loss not only of flow-ability but also of strength values. The clearly tendency and relationship of these groups of strength values are shown in Fig5. We can see in Fig5 that strength values are mainly stabilized for concretes including those with a drop of 12m height.

![Fig.5: The strength values of concretes](image)

### 4.2.2 Strengths of core samples

Two samples were taken from each area and the height/diameter ratio of core sample is 1:1.

![Fig.6: Hardened concretes and core samples](image)

### 4.3.3 Test strength values of concrete bodies

The relationship between rebounding strength and that of core samples is shown in Fig.7.

![Fig.7: The relationship between rebounding strength and that of core samples](image)

We can find from Fig.7 that the strength values of core samples in 7day and 28 day are quite stable except for 4Sq, showing the good flow-ability and compaction after high dropping inside the concrete bodies, while there is a little poor compaction in 4Sq, which can be proved by rebounding strength values.
4.4.4 Compaction test by ultrasonic pulse wave velocity method

The plots of the velocity detected in each area are shown in Fig.8.

According to the Fig.8, we can find that concretes in these two molds are generally densely compacted without obvious cavities or other defects. 4 Sq shows the lowest velocity describing the worse compaction than other areas. This tendency is fit to the former analysis.

![Fig.8: Test results of ultrasonic velocity for the No.1 and No.2 molds](image)

6. CONCLUSIONS

From the experiment on site we can draw these following conclusions.

- The flow-ability of high-point throwing non-vibration concrete is lower than that of self-compacting concrete, but it has a better cohesiveness. This concrete still has a good workability and mechanical property after 12m dropping without the time-depending loss. Therefore, the concrete here can meet the purpose of this experiment.

- The casting scope is appropriate in the range within 2m of radius from the casting point, in where the concrete has a good pass-ability through the steel bars.

- The experiment shows that concretes after high dropping even has the strength close to the normal self-consolidating concrete, indicating that after a drop of 12m, there is a relative dense compaction inside the concrete body. Strength values of core samples are stable and in agreement with the rebounding strength values. The ultrasonic pulse wave velocity test indicates the good compaction inside the concrete body except for 4 Sq of the No.2 mold, and there are no defects or air holes.

This experiment on site offers some references for the wide use of high-point throwing non-vibration concrete with satisfying properties in construction industry.

REFERENCE


