Additional adsorbed water in recycled concrete

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Abstract: Recycling the decasting concrete catches more attention in the world. It depends on the strength for construction bearing to utilize recycled concrete (RC). Mixture ratio is one key factor deciding strength, which is supported by a crucial parameter: water-cement ratio. So the calculation of unit water use in RC is the hot topic, it is crucial that additional adsorbed water should be determined. It is appropriate to adopt the form of full (or part) coarse aggregate adding natural sand. In the case of mixed coarse aggregate adding natural sand, the water in each stere of RAC should increase its percentage corresponding to the ordinary concrete in the mix proportion design, the calculating formula for the additional adsorbed water is put forward, by which the additional adsorbed water coincides better with the experimental data through verification, and which can provide a reference for the designer in RC mixed ratio.

Key words: recycled aggregate; water absorption; specific absorption; additional adsorbed water

1 Introduction

The strength of recycled concrete (RC) is decided by the unit water use of RC in allocation. Owing to the surface coarseness of recycled aggregate and appearance of a lot of edge-angles in fragmentation, mechanical damage forming lots of microcracks inside, its specific surface area would be great, so its water absorption would be more than that of ordinary aggregate. In proportioning, if water use added is less, the workability of the allocated RC can’t reach the demand of construction, if more, strength of RC will be dropped, and dry shrinkage will increase. All these are disadvantageous to structural bearing. Therefore, at the same time of ensuring the construction performance of RC, and the strength of RC cannot decrease too much, the water use in agitation should have one appropriate value, SHI et al\textsuperscript{(1)} put forward the mixture ratio design method based on free water-cement ratio. ZHANG et al\textsuperscript{(2)} put forward the water preabsorption method of recycled aggregate. In addition, The unit water use in RC should increase on the basis of ordinary concrete\textsuperscript{(3−5)}, but these references didn’t give any evident calculating formula. Thus it is necessary to research.

2 Decision of additional adsorbed water in mixture ratio design for RC

In case of the workability and strength of concrete that should meet the designing requirement at the same time, the allocation of RC can’t simply use indiscriminately the method of mixture ratio design of ordinary concrete, but it is necessary to make suitable adjustment combining the property of great specific absorption of recycled aggregate and the requirement for engineering design.

That the recycled aggregate absorbed too much water results in deduction of actually available water, so the water absorbed by the recycled aggregate more than that by the ordinary aggregate in the same mass of aggregate. Considering that the water withdrawal of recycled concrete would consist of two parts, one part is the unit water use \(W\) that is worked out by the designing method according to the mixture ratio of ordinary concrete, the other part is the water withdrawal for extra addition \(\Delta W\) that is called additional adsorbed water considering the greatness of specific absorption of recycled aggregate. Thus, the water withdrawal of unit volume of RC is \(W_{R}=W+\Delta W\), where \(W\) can be gained consulting specification for mix proportion design of ordinary concrete JGJ55-2000\textsuperscript{(6)}, \(\Delta W\) can be decided by researching the relation between the two water absorptions of recycled aggregate and ordinary aggregate.

Because the ordinary aggregate is replaced by the recycled one (water absorbed by ordinary aggregate is included in \(W\)), this part water should be deducted. In addition, the water absorption of recycled aggregate should be considered.
takes the mass of oven-dried aggregate as the reference, while the recycled aggregate itself contains a part of water, in fact, it is impossible to let all recycled aggregate be oven-dried for allocating concrete, therefore more water that should be added is that the water absorption of recycled aggregate decreases its natural water content and decreases the water that is the same mass of the water absorption of the replaced ordinary aggregate (similarly its natural water content should be decreased), the calculating formula of the additional adsorbed water using mathematical expression is as follows:

$$\Delta W = m_{RA} \times \left[ (s_{RA} - W_{RA}) - (s_{OA} - W_{OA}) \right] = (aRA) \times \left[ (s_{RA} - W_{RA}) - (s_{OA} - W_{OA}) \right]$$  \( (1) \)

where \( m_{RA} \) is the mass of recycled aggregate; \( a \) is the percentage of recycled aggregate in the total mass of aggregate; \( m_{A} \) is the total mass of recycled aggregate; \( w_{RA} \) is the natural percentage of water content of recycled aggregate; \( W_{OA} \) is the natural percentage of water content of ordinary aggregate, and \( s_{RA} \) denotes specific absorption of recycled aggregate or average specific absorption, respectively, 24 h specific absorption\([7]\) is required to be taken in the specification, actually the specific absorption of 10 min may be taken.

Therefore, in the mixture ratio design of RC, the water withdrawal of unit volume is

$$W_R = W + \Delta W$$  \( (2) \)

In Ref.\([2]\), the water preabsorption of recycled aggregate is decided according to the water absorption \( (W_{10}) \) of 10 min of recycled aggregate, and doesn’t decrease the water absorption of the same mass of ordinary aggregate, so under the same condition, \( W_{10} > \Delta W \), which is disadvantageous to enhancing the strength of RC.

3 Experimental verification on calculating formula for additional adsorbed water in mixture ratio design for RC

In order to verify the calculating formula (1) of the additional adsorbed water, \( s_{RA}, s_{OA} \) should be determined first. Because RC mainly refers to recycled coarse aggregate concrete, the specifics absorption of recycled and ordinary coarse aggregates will be analyzed with experimental method.

3.1 Raw material in test

The recycled aggregate was obtained from the decasting concrete and specimen (the coarse aggregate of original concrete was pebble) through fragmentation and screening. The ordinary coarse aggregate used is crushed stone and pebble. The index of related performance can be seen in Table 1.

<table>
<thead>
<tr>
<th>Coarse aggregate</th>
<th>Percentage of water content/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pebble</td>
<td>0.22</td>
</tr>
<tr>
<td>Crushed stone</td>
<td>0.34</td>
</tr>
<tr>
<td>Recycled aggregate</td>
<td>2.92</td>
</tr>
</tbody>
</table>

It can be seen from Table 1 that all the percentages of water content of the pebble and the crushed stone are comparatively little, while that of recycled aggregate is much great. The reason is that in the allocation of original concrete, pebble and crushed stone have absorbed too much water.

3.2 Gradation of coarse aggregate

The same gradation is adopted for ordinary coarse aggregate and recycled one, as listed in Table 2.

<table>
<thead>
<tr>
<th>Grain size/mm</th>
<th>Gradation/%</th>
</tr>
</thead>
<tbody>
<tr>
<td>5–10</td>
<td>22.65</td>
</tr>
<tr>
<td>10–20</td>
<td>32.04</td>
</tr>
<tr>
<td>20–40</td>
<td>45.31</td>
</tr>
</tbody>
</table>

3.3 Variation law of specific absorption of coarse aggregate with time

In order to get comparatively accurate data and explain the relation between the mass and the water absorption of RCA, a few groups of tests were done to the recycled coarse aggregate(RCA), the obtained varying relations of water absorption of coarse aggregate (saturated-surface-dry condition) with time are shown in Fig.1 (because the water absorption variations behind 10 min are little, only a few experiment points ahead of 60 min are expressed in the figure).

It can be seen from Fig.1 that the water absorption of coarse aggregate increases as time goes on, and the water absorption speed of recycled aggregate is greater evidently than that of crushed stone and pebble, within this course, in the first 10 min, the water absorption speed is the greatest, then it decreases and tends to saturation. The reason is that the particle edge-angles of recycled aggregate are more, and surface is rough, so that the specific surface area is great, the porosity in hardened cement pastes of lots of hardened cement mortars would be great, and there would be many microcracks in the coarse of fragmentation, therefore, the specific absorption and water absorption speed of recycled aggregate should be much greater than those of ordinary aggregate. Besides, water absorption of RCA is fundamentally proportional to its mass.