Experimental study on the effect of sustained axial tension load at early age on the tensile strength of concrete during late splitting

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Abstract. In order to study the effect of early-stage concrete loading on the tensile strength of the later splitting, a total of 7 series of specimens were designed. Through the sustained tension in early age, the effects of preloading axial tension ratio, loaded time and concrete strength on the tensile strength of concrete during splitting were discussed. A set of sustained tension device was set up by which six concrete specimens could be applied continuous pulling force together. The test results show that the sustained tension at early age has an adverse effect on the tensile strength of the late splitting. The reduction range is between 10.4% and 18.3% in the experimental parameters.

1. Introduction

Engineering projects try to shorten construction periods and save costs. The early dismantling support system has been promoted and applied in the project due to its fast turnover and low construction cost. For example, the aluminum alloy early demolition formwork will be removed around 3 days, then the multi-layer early age concrete structure and the late demolition support system will jointly withstand the construction load. Correspondingly, whether the construction load causes damage to the concrete structure at an early stage is a problem that engineers pay special attention to, and it is also a problem that must be faced in the promotion and application of the early removal of the formwork system. Jin Xianyu\(^1\) applied a certain load to the early two concretes of different strength grades and maintained the load for 30s. Tests have shown that early concrete has a certain self-healing ability and is more self-healing in a standard curing environment. Some scholars have studied the effects of vibration, shock, fatigue and creep on the mechanical properties of early concrete\(^2\)-\(^5\). However, little research has been done on the mechanical properties of 72-hour concrete structures.

Considering the concrete beam and slab as the flexural member, the tensile regions of the member under load are considered. The influence of continuous load on the performance of early age concrete is considered. The continuous load is continuous tension. Since the curing conditions provided by the on-site construction environment are generally natural watering and the ambient temperature is also random, three strength grades of C20, C30 and C40 are designed. The effect of continuous load on the splitting tensile strength of early age concrete was discussed. The effects of concrete strength, bearing axial pull ratio, loaded time on the splitting tensile strength of early age concrete were discussed.

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2. Test overview

2.1 Test raw materials and mix ratio
The conical P•O42.5 ordinary Portland cement is used; the particle size of the crushed stone is about 10~25mm; the apparent density and mud content of the sand are 2.6kg/m³ and 0.2%, respectively, and the fineness modulus is 2.7; For tap water; high-efficiency water reducer, water reduction rate is 25% to 35%; Grade II fly ash. The concrete mix ratio is shown in Table 1.

| Mix ratio of concrete (kg/m³) | cement | sand | stone | water | Water reducing agent | Fly ash |
|-------------------------------|--------|------|-------|-------|---------------------|--------|
| C20                           | 333    | 777  | 1165  | 233   | 0.025               | 37     |
| C30                           | 330    | 726  | 1088  | 202   | 1.55                | 36.5   |
| C40                           | 366    | 709  | 1063  | 220   | 0.4                 | 40.7   |

2.2 Test plan
Considering the influence of early load on the splitting tensile strength of concrete at different ages, three concrete strength grades and 7 sets of concrete specimens were designed. Seven of the groups were given long-lasting tension at the early stage. Each series contains 9 samples, 6 prisms and 3 cubes. Three of the six prisms were used as a split test to compare conventional unloading specimens, and three prisms applied a sustained load at an early stage. Three cube samples were used as the basis for determining the strength level of the 28-day concrete.

The number of each test piece is shown in Table 2. The symbols in the numbers of the test pieces in Table 2 are sequentially expressed as concrete strength, axial pull ratio, initial holding age, and holding time. For example, in C30-0.3T-1.5-7, C30 represents the design strength grade, 0.3T represents the load-bearing axial pull ratio of 0.3, 1.5 represents the initial holding age of 1.5d, and 7 represents the holding time of 7d.

The axial pull ratio $k_T$ is as shown in equation (1):

$$k_T = \frac{N_{LT}}{N_{LT}}$$  (1)

In the formula: $N_{LT}$ is the size of the applied tensile force, $N_{LT}$ is the split tensile capacity of the cube specimen for d days.

| Order number | axial tension ratio $k_T$ | holding time D | $N_{LT}$/kN | $N_{LT}$/kN | $f_{cu}, 28$ |
|--------------|--------------------------|----------------|-------------|-------------|--------------|
| C20-0.3T-1.5-7 | 0.3                      | 7              | 20.7        | 6.2         | 22.9         |
| C20-0.5T-1.5-7 | 0.5                      | 7              | 21.57       | 10.8        | 23.2         |
| C30-0.15T-1.5-7 | 0.15                     | 7              | 21.9        | 3.3         | 32.1         |
| C30-0.3T-1.5-7 | 0.3                      | 7              | 20.8        | 6.5         | 31.4         |
| C30-0.5T-1.5-7 | 0.5                      | 7              | 22.18       | 11          | 31.3         |
| C30-0.3T-1.5-14 | 0.3                      | 14             | 18.9        | 5.7         | 30.6         |
| C40-0.5T-1.5-7 | 0.5                      | 7              | 20.18       | 10          | 38.5         |

2.3 Long-term continuous axial tension loading scheme
Due to the large amount of test pieces, the workload of continuous tensile test of a single test piece is large. In order to speed up the test, a test device capable of simultaneously loading six test pieces is designed. The device comprises: a three-way reaction frame, an upper beam, a loading distribution beam, six serial connection rods, two threaded connecting rods, four limit fasteners, a gear type jack, a pressure sensor, as shown in the Fig 1(a).

The device connects three test pieces in series through the pre-embedded connecting slot iron block and the sleeve steel pipe and the connecting rod. As shown in Fig. 2 the device is symmetrically
suspended on both sides. When the specimen is cured to 1.5d, six specimens are suspended for loading. The load distribution beam is placed in the middle, and the load is continuously applied by the gear jack located at the bottom of the bottom of the load distribution beam, and the pressure sensor installed under the jack is connected with the digital readout, as shown in Fig. 1(b).

First apply a pull force of 0.1Ndt to see if the device is working properly and then unload. Based on the proposed load size, the load is applied using the same method as above and the applied load is directly read by the pressure sensor and its digital readout, and the load is maintained until the predetermined hold time is reached.

3. Splitting test results and analysis

3.1 Test phenomenon
In the early age, the damaged surface of the specimen is traversed through the coarse aggregate, and a slight cracking sound occurs when the specimen is damaged. The failure process of the test block shows brittle failure.
3.2 Early age tensile test piece test results

Test Results Analysis Table 3 shows the splitting strength of the tensile specimens at the early age and the effective values obtained according to the principle of the standard value. $NT_{ts}$ represents the splitting strength of the tensile strength test piece 28d at the early age, $N_{ts}$ stands for the splitting strength of the corresponding conventional prismatic test piece 28d. It can be seen from Table 3 that the $NT_{ts}$ of C20-0.3T-1.5-7 series concrete 28d specimens are reduced by 18.3% compared with the conventional specimen $N_{ts}$; the $NT_{ts}$ mean ratio of C20-0.5T-1.5-7 series concrete 28d test pieces; the average value of C30-0.15T-1.5-7 series concrete 28d specimens decreased by 10.4% compared with the average value of conventional test pieces $N_{ts}$; the average value of $NT_{ts}$ of C30-0.3T-1.5-7 series concrete 28d test pieces; the average value of $N_{ts}$ of conventional test pieces increased by 1.3%; the average value of $NT_{ts}$ of C30-0.5T-1.5-7 series concrete 28d specimens was reduced by 10.9% compared with the average value of conventional test pieces $N_{ts}$; C30-0.3T-1.5 series concrete 28d test pieces $NT_{ts}$: the mean value is 2.4% higher than the average value of conventional test pieces $N_{ts}$; the average value of $NT_{ts}$ of C40-0.5T-1.5-7 series concrete 28d test pieces is 10.4% lower than the average value of conventional test pieces $N_{ts}$.

It can be seen from Table 3 that most of the $NT_{ts}$ mean values are less than $N_{ts}$, and the late-stage splitting tensile strength decreases by 10.4% to 18.3% after long-term exposure in the early age. Among them, when the C30 series axial pull ratio $k_T=0.5$, the splitting strength of the test pieces is generally about 10% compared with the conventional test pieces. It can be seen that the internal compactness and the degree of micro-crack expansion of the specimen after bearing are still affected by the splitting strength of the specimen at the later stage.

| Test piece number | $NT_{ts}$/kN | $N_{ts}$/kN | $(NT_{ts}-N_{ts})/N_{ts}$ |
|-------------------|--------------|-------------|---------------------------|
| C20-0.3T-1.5-7    | 73.2         | 84.8        | 18.3%                     |
| C20-0.3T-1.5-7    | 85.5         | 88.1        |                           |
| C20-0.3T-1.5-7    | 68.1         | 69.8        |                           |
| C20-0.5T-1.5-7    | 86.8         | 85.9        |                           |
| C20-0.5T-1.5-7    | 68.9         | 73.8        | 11%                       |
| C20-0.5T-1.5-7    | 90.5         | 53.8        |                           |
| C30-0.15T-1.5-7   | 107.4        | 66.2        |                           |
| C30-0.15T-1.5-7   | 75.6         | 81.4        | 10.4%                     |
| C30-0.15T-1.5-7   | 80.8         | 93.1        |                           |
| C30-0.3T-1.5-7    | 102.4        | 85.5        |                           |
| C30-0.3T-1.5-7    | 81           | 82.9        | 1.3%                      |
| C30-0.3T-1.5-7    | 89.6         | 91.2        |                           |
Conclusions
The early tensile force applied to the concrete has a certain influence on the late splitting tensile strength, which is roughly reduced by 10.4% to 18.3%. It shows that the application of long-lasting tensile force in the early age makes the internal compactness and micro-crack expansion of the specimen have a certain influence on the splitting strength of the specimen at the later stage.

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