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PROPOSED BURIED WEIGHT TEST AS METHOD OF TESTING FOR SETTING TIME OF CONCRETE MIXTURES

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In this study, we examined method of test for setting time of concrete mixtures. Generally, the setting time of concrete mixtures is demanded by variation of penetration resistance, which is measured by manual labor for about eight hours. This measurement takes considerable effort. In late years, automatic devices to measure penetration resistance are commercially available, however the price is high. To solve these problems, we proposed a new low-effort and low-cost method: Embedded Weight Test. In the Embedded Weight Test, an embedded weight is hung with a line in the concrete mixture, and the tension of the line is measured by a data logger. The tension of the line had a variation point. The variation point is regarded as the time when the concrete mixture begins to vary from liquid to solid. As a result pf Embedded Weight Test with cement paste, the variation point of the tension was correlated with the initial setting time, which was defined by ISO 9597.Similar results were obtained when Embedded Weight Test was carried out with mortar. The variation point of the tension was correlated will help to estimate the time such as limits from mixing to the completion of placing or limit for intervals placing operations.

Keywords: Embedded weight test, Penetration test, Cement paste, Mortar.

1 INTRODUCTION

The viscoelastic nature of fresh concrete changes over time along with the hydration of the cement. The moment, when the viscoelastic nature changes dramatically, is treated as the start and end time of setting. The setting time is used as data to judge the allowable time between the pouring of previous and new concrete materials, the timing for trowel finishing, the tamping period, the timing and speed of sliding the sliding form, demolding timing, etc. The setting time of concrete can be said to be an important characteristic that has an effect on concrete work execution planning. In Japan, setting time is measured by a penetration test (a measurement method stipulated by JIS R 5201), which requires 8 h of manual labor. In recent years, unmanned equipment to measure the setting time has been released, but such equipment is very expensive.

In this paper, we performed basic research in order to propose a new method to measure setting time with the objective of reducing the labor involved in measuring setting time, reducing costs, and eliminating human error. As similar study, Koyama (2005) proposed a prediction of setting time by the temperature history; Aho (2010) proposed to grasp progress of setting by the electric conductivity; Watanabe (2013) proposed a decision of setting by the lightness change of the sample surface blown with air. In contrast, the variables for measurement upon which we focus were the external forces acting on a body in the concrete: gravity, buoyancy, and reactive force. The sum of the external forces is considered to change around the time of setting. In this paper, a Buried Weight Test was proposed as a test by which to measure the external forces incident on the body around the time of setting. We furthermore attempted to apply the Buried Weight Test as a method for measuring the setting time of cement paste and mortar. This paper is a report of these results.

2 EXPERIMENT SYNOPSIS

Table 1 shows the materials used in this paper. Ordinary Portland Cement (OPC), fly ash (FA), ground granulated blast-furnace slag (GGBS), tap water, and fine aggregate were used. The FA was of a quality conforming to JIS A 6201 variety II, and the GGBS was of a quality conforming to JIS A 6202 class 4000.

Table 1. Materials.

Material and Properties
Ordinary Portland Cement（OPC） density: 3.16g/cm³ specific surfly ashce area: 3300cm^2/g
Fly Ash type-II（FA） density: 2.25g/cm³ specific surfly ashce area:3470cm^2/g ignition loss: 2.3%
Ground Granulated Blast-furnace Slag（GGBS） density: 2.95g/cm³ specific surfly ashce area:4160cm^2/g
sea sand density in saturated surface-dry condition: 2.25g/cm³
Tap water（W）

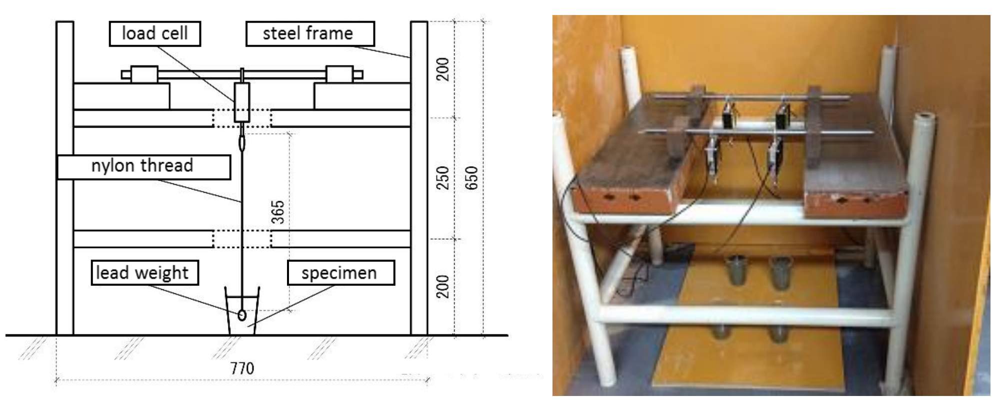
In the test on the cement paste, three varieties of sample were used: 1) plain OPC cement paste, 2) cement paste with granulated sugar added, and 3) Cement paste in which OPC and FA were mixed at a ratio of 9:1. The amount of tap water necessary to obtain a standard consistency with respect to 500 g OPC was 140 g for the OPC preparation and 144 g for the preparation that included FA. In the test on mortar, W/OPC = 50% was made the basic preparation. A preparation where 10% of the OPC was substituted with FA and a preparation where 45% of the OPC was substituted with GGBS were also created. Preparations in which granulated sugar was added to these three varieties were also created for a total of six mortar samples. The purpose of granulated sugar is to delay the setting time. In the case approximately 0.05% granulated sugar is added to cement, the start of setting is known to be delayed by 1-2 hours.

In the test on cement paste, measurement of the start time and end time of setting was performed by means of a penetration test conforming to JIS R 5201. Also, in the test on mortar, the penetration resistance value was measured by means of a penetration test conforming to JIS R 1147.

3 BURIED WEIGHT TEST

The Buried Weight Test is a new test proposed in this paper in which a weight hung vertically by a thread is implanted in the test piece prior to setting and the time-dependent change of the tension incident on the thread is measured. Technical drawing and photograph of Buried Weight Test show Figure 1. A load cell (capacity 10 N) that responds to tensile load was used as an apparatus to measure the change in tension. The tension was measured in 1 sec intervals using this load cell and 5 min averages were used as a single test value. In addition, a steel frame, a polystyrene cup, a lead weight, and nylon thread were used. On the premise of the sample container being thrown away, the polystyrene cup was selected because it is comparatively cheap and has low water absorbency. During the selection of the weight, a comparison was made of a 110 g weight and a 35 g weight. As a result, both weights had approximately the same sensitivity to changes in tension, and so the comparatively cheaper 35 g weight was selected. For the thread, the comparison was made of comparatively elastic nylon thread and non-elastic polyethylene thread. Since the polyethylene thread was overly sensitive to external factors, the nylon thread by which a comparatively stable value could be obtained was selected. The diameter of the thread used was 0.17 mm and its strength was 18 N.

Changes in air temperature can be given as a principal ambient factor that should be eliminated in the Buried Weight Test. Figure 2 shows the method by which the impact of changes in the ambient temperature was eliminated from the tension that arises in the thread. The corrected value is taken to be the tension of the line connected to the weight embedded in the sample subtracting the tension of the thread connected to the weight at rest on the ground. By means of this correction, the thermal expansion of the steel frame and the thread according to changes in the ambient temperature can be eliminated. Thereafter, the corrected value is used as the tension generated in the thread.



(a) (b)

Figure 1. Buried Weight Test; (a) technical drawing; (b) photograph.

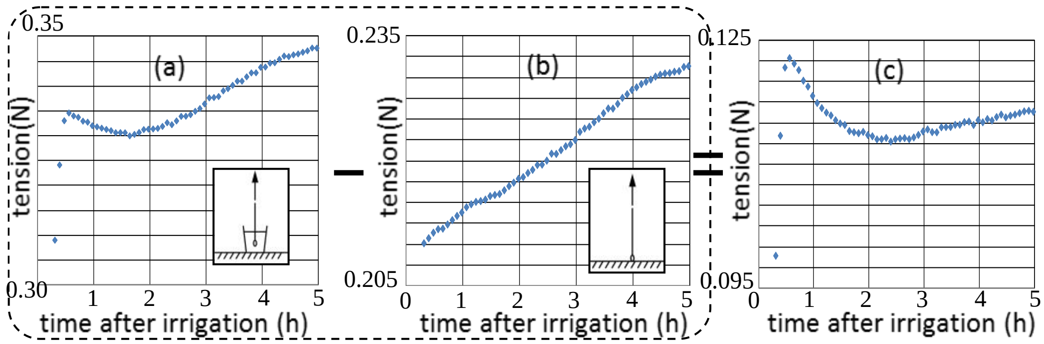


Figure 2. Principal ambient factor: (a) bury; (b) ground holder; (c) corrected value.

4 BURIED WEIGHT TEST ON CEMENT PASTE

Figure 3 shows the changes over time of the tension (the corrected value of the previous section) of the thread connected to the weight embedded in the cement paste. The tension that occurs in the thread increased considerably 20-30 min directly after embedding the weight in the sample. This is probably due to the process whereby the weight sinks into the cement paste over time. The thread was probably pulled over a 20-30 min period until it was stretched straight, and the tension increased. Because of this, the increase in tension during the 20-30 min after the start of the tests was masked.

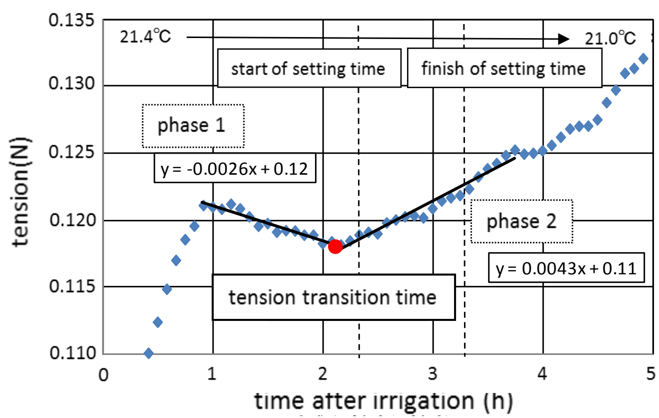


Figure 3. Buried weight test on cement paste (example report).

Thereafter, the tension transitioned at a fixed rate of change for a while. This phase is called Phase 1 for convenience. After Phase 1, the tension first increased by enhancing the increasing tendency or starting to increase from a decreasing tendency and then changed at a fixed rate again. This phase is called Phase 2 for convenience.

The boundary between Phase 1 and Phase 2 is defined as the tension transition time (the red dot in the diagram). Figure 4 shows the relationship between the tension transition time given by the Buried Weight Test and the start of setting time given by the penetration test (JIS R 5201). A correlation coefficient of 0.86 was observed between the two. This probably means that the start of setting time of the cement paste can be estimated according to the Buried Weight Test.

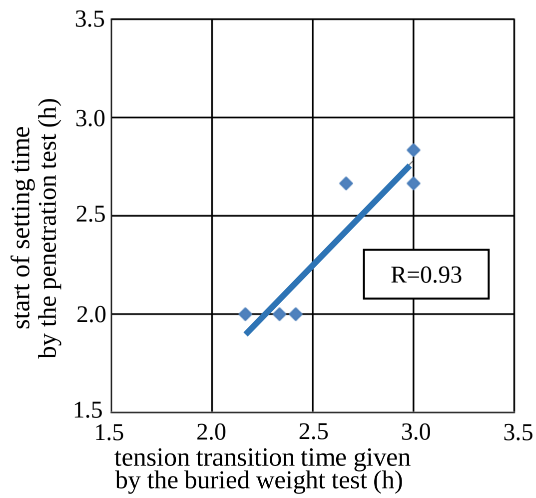


Figure 4. Relationship between tension transition time and start of setting time.

5 BURIED WEIGHT TEST ON MORTAR

Figure 5 shows the measurement data for the Buried Weight Test using mortar as a sample. The times at which the penetration resistance value reached 0.1 N/mm^2, 0.5 N/mm^2, 1.0 N/mm^2, 3.5 N/mm^2 (start time defined by JIS) and 28.0 N/mm^2 (finish time defined by JIS) have been added to the same diagram.

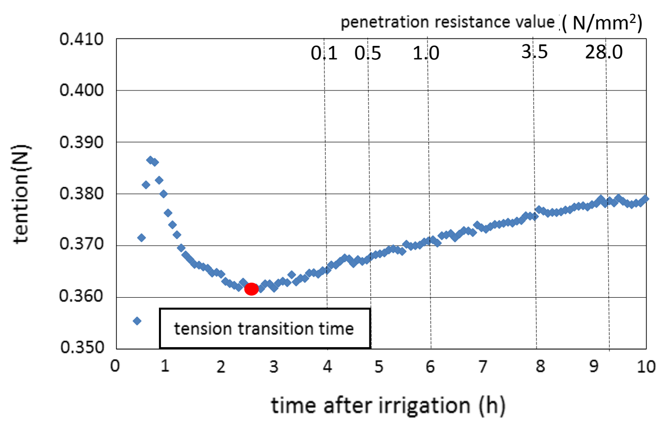


Figure 5. Buried weight test on mortar (example report).

The tension transition time (the red dot in the diagram) appeared before the penetration resistance value reached 0.1 N/mm^2. Figure 6 shows the relationship between the tension transition time and the time when the penetration test value reached a constant value. The correlation coefficient for the tension transition time and the time at which the penetration resistance reached 0.1N/mm^2 was 0.43. According to the test results, the tension transition time may correspond to a time at which the viscoelastic nature changes before a penetration resistance value for the fresh mortar arises. In the paper by Matsufuji (1983), a period of 1.5-3 h was given as the allowable work time, in which the physical properties of fresh mortar began to change considerably, because the work was performed adeptly and the quality of the structure was good. In future, it will be necessary to measure the time at which the flow value changes as a time at which the viscoelastic nature changes prior to the penetration resistance value occurring and investigate its relationship with tension transition time.

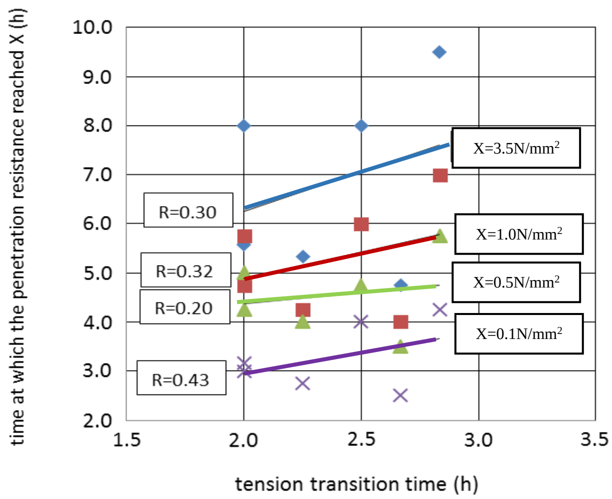


Figure 6. Figure of relationships.

6 CONCLUSION

- A Buried Weight Test was proposed as a test method by which to measure the change in physical properties of still-soft cement paste and mortar.
- It is possible to obtain the tension transition time from the Buried Weight Test. The tension transition time of cement paste showed a positive correlation with the start time given by the penetration test. The tension transition time of mortar showed a positive correlation with the time when the penetration resistance value reached 0.1 N/mm^2, but the correlation coefficient was comparatively small.

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