Outline of “Effects of Stiffness-reducing Agent for Concrete”

「コンクリートのこわばりを低減する化学混和剤の効果」の概要




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1. Introduction

In recent years, as part of the i-Construction efforts advocated by the Ministry of Land, Infrastructure, Transport and Tourism, active use of precast concrete members has been promoted from the perspective of productivity improvement in concrete work, and guidelines have been established for the use of cast-in-place concrete with improved fluidity. These efforts are aimed at optimizing concrete work, but the recent increase in the density of reinforcement in concrete structures accompanying the increase in the required level of seismic performance has increased considerably the difficulty of on-site concrete work. However, it may be difficult to avoid the occurrence of initial defects such as honeycomb and insufficient filling by simply increasing the fluidity of concrete. Under actual pumping conditions, even concrete with predetermined fresh properties under agitation can have greatly reduced fluidity when stationary, and the shear stress for re-fluidization increases considerably. This is major concern.

The authors have defined this decreased fluidity of fresh concrete as “stiffening” and have developed a chemical admixture with an obvious anti-stiffening effect. This study investigated the hypothesized mechanism for the occurrence of stiffness and verified experimentally the effectiveness of the stiffening reduction agent.

2. Stiffness of Concrete

The term “stiffening” applies to a soft object that becomes hard, unnaturally stretched, or stiff. Concrete becomes stiffened when its fluidity while moving is decreased or when its resistance to moving while stationary is increased. Stiffening is a qualitative term, but the phenomenon involves very complex physical and chemical factors. The stiffening phenomenon has been defined in previous studies[1, 2].

3. Test Method for Evaluating Stiffness of Concrete

In the static slump test, concrete is packed in the slump cone used in the slump test of JIS A 1101, and the degree of stiffening of the concrete is evaluated simply by the slump after being static for a predetermined time. Concrete slump is highly correlated with its (apparent) yield value, with the apparent yield value expected to increase as the concrete slump (static slump) decreases. The following shows the results of a static slump test for concrete with a designated slump of 21 cm. In this experiment, to verify the effect of the anti-stiffening agent, it was added to the concrete sample 30 min after being mixed, and the properties were compared with those of the base concrete as the control. **Fig. 1** shows photographs of the base concrete and treated concrete after the static slump test. For the base concrete, the static slump was 6.0 cm at 60 min post-mixing, considerably lower than that in the normal slump test. This suggests that the apparent yield value increased and the fluidity decreased considerably as the

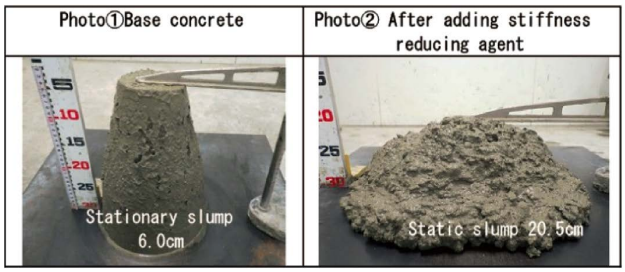

Fig. 1 Comparison of static slump test results

concrete stiffened, as described above.

On the other hand, when the anti-stiffening agent was added, the slump of the concrete kept in the static state was 20.5 cm, not much different from that in the normal slump test.

The static slump test is relatively simple, but for high-fluidity concrete whose slump flow is suppressed by a chemical admixture, the potential energy retained by keeping the concrete inside the slump cone becomes kinetic energy upon lifting the cone, resulting in normal slump flow. Therefore, the applicability of this method for evaluating the stiffening of a high-concentration suspension was evaluated using a rotary vane-type rotational viscometer, given that the shear stress increases greatly by keeping the concrete static. Experiments were also conducted on fresh mortar using the vane shear test (**Fig. 2**), which is used in practice to determine the undrained shear strength of clay. The measurement results of the rotational viscometer and the vane shear test are compared in **Fig. 3**. The relationship between the two is represented by a regression line up to a shear stress of about 3000 Pa, after which the value measured in the vane shear test

Fig. 2 Vane shear test

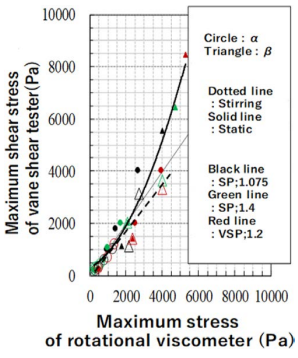

Fig. 3 Comparison of results from rotational viscometer and vane shear tester

under static conditions becomes larger and increases exponentially. In manual measurements (i.e., the vane shear test), it is difficult to precisely control the acceleration, and the initial velocity may be higher than that in mechanical measurement. In other words, compared to the results by mechanical measurement, the shear stress in the vane shear test is considered to be higher because of the shear-rate dependence.

In this work, the test method for evaluating the stiffening of concrete was verified through experiments. By using a vane shear tester, it was possible to easily obtain a value that approximated the measurement result of a rotational viscometer, and can evaluate the phenomenon that the apparent yield value increases due to stiffness, especially in the range of extremely low flowability.

4. Conclusion

In this work, because it is important to control the stiffness of concrete in the field, the mechanism of stiffening in concrete was hypothesized, and the effect of a chemical admixture (anti-stiffening agent) that suppresses the agglomeration of high-concentration cement suspensions was verified through experiments. Also, a vane shear test was proposed as a simple test to evaluate the degree of stiffening of concrete, and an attempt was made to quantify the phenomenon in which the apparent yield value increases considerably because of stiffening. The present work led to the following knowledge:

(1) The stiffness of concrete varies with composition.
(2) The stiffness can be alleviated by adding a special admixture.

In the future, the use of a stiffness-reducing agent on site is expected to lead to improved productivity in the pumping work.

References

[1] Nemoto, H., Hirano, S., Nishi, H., Date, S.: *Experimental verification on improvement of properties of fresh concrete using stiffening inhibitor*, Proceedings of the Japan Concrete Institute, Vol. 39, No. 1, JCI, Tokyo, pp. 1261-1266, Jul 2017 (in Japanese).

[2] Nemoto, H., Hirano, S., Date, S., Hashimoto, S.: *Admixture to reduce stiffening in concrete*, Concrete Journal, Vol. 57, No. 1, JCI, Tokyo, pp. 16-19, Jan 2019 (in Japanese).