水和反応の進行がセメント粒子の表面状態と フレッシュモルタルの性状に及ぼす影響

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要旨

自己充填コンクリートは打設完了時まで十分な自己充填性能の保持が求められることから，製造時のみならず運搬を経た打設現場においても確実な品質管理および必要に応じて調整を必要とする。これは，自己充填コンクリートの採用を躊躇する要因の一つとなり得る。フレッシュコンクリートの自己充填性能低下の主要因は水和反応の進行である。水和反応進行の抑制方法の一つとして，有機系凝結遅延剤の一種として知られる砂糖の添加がある。水和反応の進行抑制が可能な砂糖の添加は，自己充填性能低下のメカニズムを明らかにし，フレッシュコンクリートの自己充填性能の経時安定化のための技術開発に繋がる可能性がある。

本研究の目的は，時間経過や砂糖添加の有無に応じて変化する水和反応の進行度を定量化し，水和反応の進行がフレッシュモルタルの自己充填性能に及ぼす影響を解明することである。セメント粒子の状態に着目して比表面積と粒度分布の測定により水和反応の進行度の定量化を試みた。自己充填性能の構成要素であるフレッシュモルタルのせん断変形抵抗性と直応力下でのせん断強度を，時間経過や砂糖添加の有無により水和反応の進行度を変化させて測定を行った。

練上がりから 180 分後では，水和反応の進行度に応じて比表面積の測定結果に差が表れた。一方，水和反応初期であるため粒子同士が凝集する段階には至らず，粒度分布の測定結果には明確な差が表れなかった。

せん断変形抵抗性を測定する粘度値は，水和反応の進行に伴い上昇し，比表面積の測定結果と相関があった。同様に比表面積の測定結果と相関があったロート流下速度と粘度値は，練混ぜ方法ごとに相関があった。さらに，比表面積の測定を行った練上がり直後と 180 分後の練混ぜ方法と増粘剤添加の有無ごとのロート流下速度と粘度値は，非常に高い相関を示した。

直応力下でのせん断強度は，砂糖添加の有無による 120 分後までの水和反応の進行度の違いでは大きな差は無かった。粘性付与効果のある増粘剤を添加すると，時間経過後にせん断強度が上昇した。砂糖・増粘剤の両方を添加すると，固体粒子間摩擦の増加によりせん断強度が大きく上昇した。砂糖添加による水和反応進行の抑制効果は，フレッシュモルタルが動き出す瞬間の最大静摩擦力ではなく，流動性の経時安定化による動摩擦力の上昇抑制にあるものと考察した。

Effect of Progress of Hydration on Surface Condition of Cement Particle and Flowability of Fresh Mortar

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ABSTRACT

Since self-compacting concrete is required to maintain sufficient self-compacting performance until the completion of casting, reliable quality control and adjustment as necessary are required not only during manufacturing but also at the casting site after transportation. This can be one of the factors that hesitate to adopt self-compacting concrete. The main factor for the deterioration of the self-compacting performance of fresh concrete is the progress of the hydration of cement. One of the methods for mitigating the progress of the hydration is the addition of sugar to the mix, which is known as a kind of organic coagulation retarder. The addition of sugar, which can mitigate the progress of the hydration, may contribute to the mechanism of deterioration of self-compacting performance and lead to the development of technology for stabilizing the self-compacting performance of fresh concrete over time.

The purpose of this study is to quantify the progress of the hydration, which changes with the passage of time and the presence or absence of sugar, and to elucidate the effect of the progress of the hydration on the self-compacting performance of fresh mortar. Focusing on the state of cement particle, the author attempted to quantify the progress of the hydration by measuring the specific surface area and particle size distribution of cement particles. The shear deformation resistance of fresh mortar, which is a component of self-compacting performance, and the shear strength under stress were measured by changing the degree of the hydration depending on the passage of time and the presence or absence of sugar.

At 180 minutes after mixing, there was a difference in the specific surface area depending on the degree of the hydration. On the other hand, since it was in the early stage of the total hydration process for a few days, the particle did not reach the stage of agglutination, and there was no clear difference in the measurement results of the particle size distribution.

The viscosity value for measuring shear deformation resistance increased as the hydration progressed, and was correlated with the specific surface area. Similarly, the funnel discharging rate and viscosity value, which were correlated with the measurement results of specific surface area, were correlated for each kneading method. Furthermore, the funnel discharging rate and viscosity value immediately after mixing and 180 minutes after mixing, for which the specific surface area was measured, showed a very high correlation depending on the mixing method and the presence or absence of viscosity modifying agent (VMA).

The shear strength under normal stress did not differ significantly depending on the progress of the

hydration up to 120 minutes with or without sugar. When a VMA with a viscosity-imparting effect was added, the shear strength increased over time. The addition of both sugar and VMA resulted in the shear strength increased significantly due to the increase in friction between solid particles. It is possible that the effect of suppressing the degree of the hydration by adding sugar was not the maximum static friction force at the moment when the fresh mortar started to move, but mitigating the increase of the dynamic friction force due to the stabilization of fluidity over time.