Flowable Concrete During Compaction

Effect of External Vibration on the Evolution of Yield Stress and Viscosity and the Resulting Deaeration and Segregation Behaviour

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1 Motivation and Aim

Flowable concrete represents the link between Self Compacting Concrete (SCC) and conventional vibrating concrete. They exhibit outstanding workability but have to be slightly compacted to ensure sufficient deaeration. However, a too intense compaction may cause segregation of the coarse aggregate and thus impaired durability. Numerous studies have been carried out to rheologically characterize flowable concretes. However, only a few [1-4] were performed with simultaneous external compaction. Nevertheless, to ensure adequate deaeration and sufficient robustness against segregation, it is necessary to know the rheological properties during compaction. For this aim, rotational vane rheometer, deaeration and segregation tests during compaction were performed.

2 Materials and Methods

Materials and Mix Design

OPC 42.5 N, fly ash, naturally rounded sand 0/4 mm, coarse aggregate 4/16 mm and PCE-based superplasticizer (SP) were used. For variation of the (uncompacted) plastic viscosity μ, a 1st series of concretes (μ^-, $\mu°$, μ+) was differed in its water to binder ratio *w/b* and thus relative solid concentration (direct effect on μ), but constant paste volume, binder composition and grading curve of the aggregate. The SP content was adjusted to reach a comparable dynamic yield stress ($\tau_{0D}°$). Furthermore a 2nd series based on mix design of $\mu°$ but with a variation of the SP content and thus the initial dynamic yield stress (τ_{0D}^-, $\tau_{0D}°$, τ_{0D}^+) was investigated.

Compaction

The compaction work *W* was determined by assuming a harmonic sinusoid of the vibration table. The compaction scenarios represented the range from under-compaction (W~300 J), over usual compaction for flowable concrete (W~2,500 J) to over-compaction with concrete segregation (W~8,000 J).

Test Procedure

The test procedure began 19 min after water addition (after 30 s of remixing the concrete). The rheological investigations were carried out in a 4-bladed rotational vane-in-cup concrete rheometer with a speed-controlled step profile (8 steps, 8 s each, rotation speed stepwise reduced from 0.5 rps to 0.03 rps). The dynamic yield stress τ_{0D} and plastic viscosity μ were determined under the assumption of Bingham's law. For measurements during compaction, the cup of the rheometer was rigidly fixed to a vibrating table and thus the concrete inside could be compacted, while the vane paddle was decoupled from the vibration. The air void content was determined based on EN 12350-7 and the coarse aggregate segregation by cylinder segregation test [5] both without and with a successive increase in compaction by increasing either frequency or duration of the vibration table.

3 Results and Discussion

Figure 1 exemplarily shows the development of τ_{0D} (left) and μ (right) under the effect of *W* for varying μ^+, $\mu°$ and μ^- but with comparable $\tau_{0D}°$. Compaction reduces both τ_{0D} and μ of all tested concretes. The reduction in τ_{0D} was linked to the initial concrete viscosity: for the high viscous concrete μ^+, even low compaction led to a significant reduction in τ_{0D}, whereas just a slight decrease could be observed for concrete μ^-, Figure 1 (left). Even a light compaction was sufficient to reduce μ of all investigated concretes by 30 to 50%, see Figure 1 (right).

The effect of W on the concretes with varying τ_{0D} but constant $\mu°$ showed comparable results to the behaviour of $\tau_{0D}°/\mu°$ in Figure 1. The development of μ under compaction proved to be largely independent of the initial τ_{0D}. Thus, the behaviour for $\tau_{0D}°/\mu°$ shown in Figure 1 (right) can also be assumed as representative for $\tau_{0D}^-/\mu°$ as well as $\tau_{0D}^+/\mu°$.

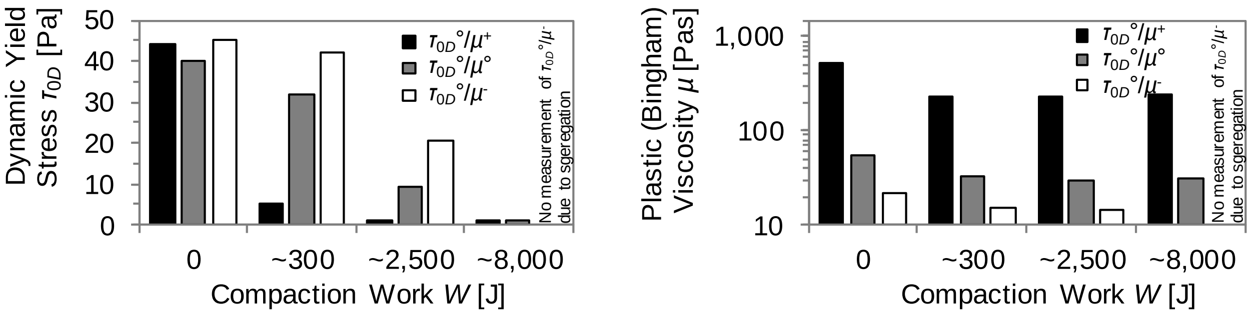

Figure 1: Evolution of dynamic yield stress (left) and plastic viscosity (right) of concretes μ^-, $\mu°$ and μ^+ with yield stress $\tau_{0D}°$ as function of the compaction work W

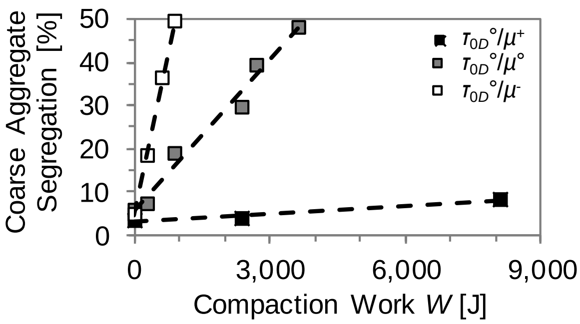

Figure 2: Segregation of concretes μ^+, $\mu°$ and μ^- with yield stress $\tau_{0D}°$ as a function of compaction work W

Figure 2 shows the segregation behaviour of concretes μ^+, $\mu°$ *and* μ^- with yield stress $\tau_{0D}°$ as a function of W. The low viscos concrete μ^- segregates significantly even at low W. With increasing viscosity, segregation is less affected by the compaction because high viscos concretes also exhibit high viscosity during compaction, which counteracts segregation. As expected, the robustness increased as well with increasing initial yield stress. Furthermore, the reduction of the initial viscosity led to improved deaeration behaviour, since the low viscous concretes had the lowest viscosity even during compaction.

4 Conclusions

The rheological, deaeration und segregation behaviour of flowable concretes with varied yield stress or viscosity were investigated in dependency of compaction intensity. It was found that yield stress and viscosity were reduced during compaction and that the magnitude of that reduction is directly linked to compaction intensity. Furthermore, concretes with high initial (not compacted) yield stress or viscosity showed also high values during compaction. This explains that highly viscous concretes showed higher robustness, but also a deteriorated deaeration.

References

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