High Torque Vane Rheometer for Concrete: Principle and Validation from Rheological Measurements

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Abstract:
A high torque vane rheometer is used to measure the yields stress of cement-based materials. It is shown that this apparatus is suitable for the evaluation of the yield stress of various concretes and mortars in the fresh state in comparison with slump tests realized with ASTM Abrams cone. Then, the rheological properties (yield stress and shear flow behaviour) of a homogeneous kaolin clay suspension are studied with the apparatus and favourably compared with other rheometers and geometries.

Zusammenfassung:
Ein Schaufelrheometer, das für hohe Drehmomente entwickelt wurde, wird verwendet, um die Fließspannung in Betonmaterialien zu messen. Es wird gezeigt, dass diese Apparatur für die Bestimmung der Fließspannung von unterschiedlichen Zement- und Mörtelmaterialien in ihrem Ausgangszustand geeignet ist, vergleichbar mit dem Abschwungtest unter Verwendung des ASTM Abrams-Kegels. Die rheologischen Eigenschaften (Fließspannung und Verhalten in Scherung) einer homogenen Kaolin-Suspension wird mit dieser Apparatur untersucht und mit anderen Rheometern und Geometrien verglichen.

Résumé:
Un rheomètre à haut couple équipé d'une géométrie vane est utilisé pour mesurer le seuil de mise en écoulement de matériaux cimentaires. Il est montré que cet appareil est approprié pour évaluer le seuil de mise en écoulement de différents bétons et mortiers à l'état frais en comparaison aux seuils déterminés au cône d'Abrams. Finalement, les propriétés rhéologiques (seuil d'écoulement et comportement sous cisaillement) d'une suspension d'argile de kaolin sont étudiées avec le rhéomètre à béton, et favorablement comparées à celles obtenues par d'autres rhéomètres et géométries.

Key words: Vane rheometer; fresh concrete; rheology, yield stress; slump

1 INTRODUCTION

Cement-based mixtures and concretes, as many suspensions, are yield stress materials including also thixotropic effects due to cement hydration. So a minimum stress has to be applied to the material for irreversible deformation and flow to occur. The yield stress of concrete is of great interest in practice for transportation, pumping and casting, and this rheological parameter plays a great role in formwork pressure development [1–3], sedimentation [4] and occurrence of distinct layer casting [5]. The yield stress of concrete is currently evaluated from practical tests [6 - 8], and from the slump test in particular. The slump test is a simple test which is used for a long time to evaluate the workability of concrete. The slump test consists of a mold of a given conical shape which is filled with the tested material. The mold is lifted and the material flows under gravity on a horizontal smooth metallic plate. The slump *S* is the difference between the height of the mold at the beginning of the test and that of material after flow stoppage. Several attempts have been made for determining the yield stress of concrete from the slump test [9–15]. Previous works have shown that concrete rheometers can also be used to evaluate the rheological properties of fresh concrete, and the yield stress in particular [16, 17]. The principle of these rheometers

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which is similar to the shear rate range obtained by Heirman et al [18] with the last version of the BML viscometer. As can be seen, the parallel plate and high torque vane data compare well within the shear rate range of 0.5 to 10 s^{-1}. This allows to conclude about the efficiency of the high torque vane rheometer in shear flow measurement. Finally, it is shown that the clay suspension investigated seems to behave as a simple shear thinning material. There has been some change in clay suspension structure during the high preshear. As no resting time was applied before the descending ramp, and the time of this ramp is very short, the suspension does not retrieve its initial structure. However, at the flow stoppage, the yield stress value tends to 296 ± 2 Pa. This is different and lower than the yield stress at which the flow starts which is obtained from the vane method.

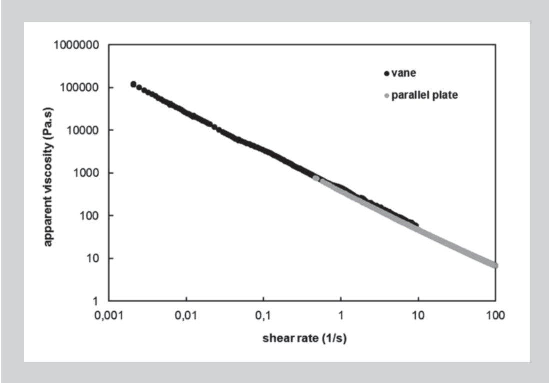

Figure 4: Apparent viscosity of kaolin clay suspension versus shear rate – comparison between the high torque vane rheometer and the parallel plate geometry.

5 CONCLUSION

In this paper, a high torque vane rheometer was used to evaluate the yield stress of various concretes and mortars. It was concluded that this rheometer is able to correctly evaluate the yield stress of these materials in comparison with slump test. Results are in agreement with the numerical prediction between slump and yield stress of concretes, as previously shown in the literature. The high torque vane rheometer was also tested with a homogeneous kaolin clay suspension. It was shown that the yield stress and the shear flow behavior of this suspension are correctly predicted by the vane rheometer, the results being compared to those obtained from other rheometers and geometries. Once validated, the concrete rheometer with the vane geometry has to be used now to investigate the rheological properties of concretes in the fresh state in relation with their composition. This is the objective of future works.

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