Determination of the Rheological Parameters of Self-Compacting Concrete Matrix Using Slump Flow Test

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Abstract:
The classification of a concrete mixture as self-compacting (SCC) is performed by a series of empirical characterization tests that have been designed to assess not only the flowability of the mixture but also its segregation resistance and filling ability. The objective of the present work is to correlate the rheological parameters of SCC matrix, yield stress and plastic viscosity, to slump flow measurements. The focus of the slump flow test investigation was centered on the fully yielded flow regime and an empirical model relating the yield stress to material and flow parameters is proposed. Our experimental data revealed that the time for a spread of 500 mm which is used in engineering practice as reference for measurement parameters, is an arbitrary choice. Our findings indicate that the non-dimensional final spread is linearly related to the non-dimensional yield-stress. Finally,there are strong indications that the non-dimensional viscosity of the mixture is associated with the non-dimensional final spread as well as the stopping time of the slump flow; this experimental data set suggests an exponential decay of the final spread and stopping time with viscosity.

Zusammenfassung:
Die Klassifizierung von Betonmischungen zur Selbstkompaktifizierung (SCC) wird mit Hilfe einer Reihe empirischer Charakterisierungsversuchen durchgeführt, die entworfen wurden, um nicht nur die Fließfähigkeit der Mischungen zu bestimmen, sondern auch ihr Segregationsverhalten und ihre Füllfähigkeit. Das Ziel der vorliegenden Arbeit ist, die rheologischen Eigenschaften der SCC-Matrix, der Fließspannung und der plastischen Viskosität für Messungen von sogenannten Slump-Strömungen zu evaluieren. Der Schwerpunkt der Slump-Strömungsmessungen lag in dem Fließregime. Ein empirisches Modell, dass die Fließspannung des Materials mit den Fließparametern in Verbindung setzt, wird aufgestellt. Unsere experimentellen Daten zeigen, dass die Zeit für die Ausbreitung von 500 mm (die in der ingenieurwissenschaftlichen Praxis als Referenz für Messparameter verwendet wird) nur eine willkürliche Wahl darstellt. Unsere Ergebnisse belegen, dass die dimensionslose Endausbreitung linear zu der dimensionslosen Fließspannung in Beziehung steht. Darüber hinaus existieren starke Hinweise, dass die dimensionslose Viskosität der Mischung mit der dimensionslosen Endausbreitung und mit der Stoppzeit des Slump-Strömung zusammenhängt. Die experimentellen Daten deuten einen exponentiellen Abfall der Endausbreitung und der Stoppzeit mit der Viskosität an.

Résumé:
La classification des mélanges de bitumes comme auto-compactant (SCC) est établie par une série de tests empiriques de caractérisation qui ont été développés pour établir non seulement leur capacité à s'écouler mais aussi leur résistance à la sédimentation et leur capacité à remplir. L'objectif de ce travail est de corréler les paramètres rhéologiques des matrices SCC, la contrainte seuil et la viscosité plastique, aux mesures d'écoulement en plan incliné. Le focus de la recherche sur le test du plan incliné est sur le régime d'écoulement pleinement établi, et un modèle empirique reliant la contrainte seuil aux paramètres d'écoulement et du matériau est proposé. Nos données expérimentales révèlent que le temps pour un étalage de 500 mm, qui est utilisé comme une référence dans la pratique pour une mesure des paramètres, est un choix arbitraire. Nos découvertes indiquent que l'étalage final adimensionnel est relié linéairement à la contrainte seuil adimensionnelle. Enfin, il y a de fortes indications que la viscosité adimensionnelle du mélange est associée à l'étalage final adimensionnel, ainsi qu'au temps d'arrêt de l'écoulement incliné. Cet ensemble de données expérimentales suggère un décroissement exponentiel de l'étalement final et du temps d'arrêt avec la viscosité.

Key words: self compacting concrete, rheology, slump flow, yield stress, dimensional analysis

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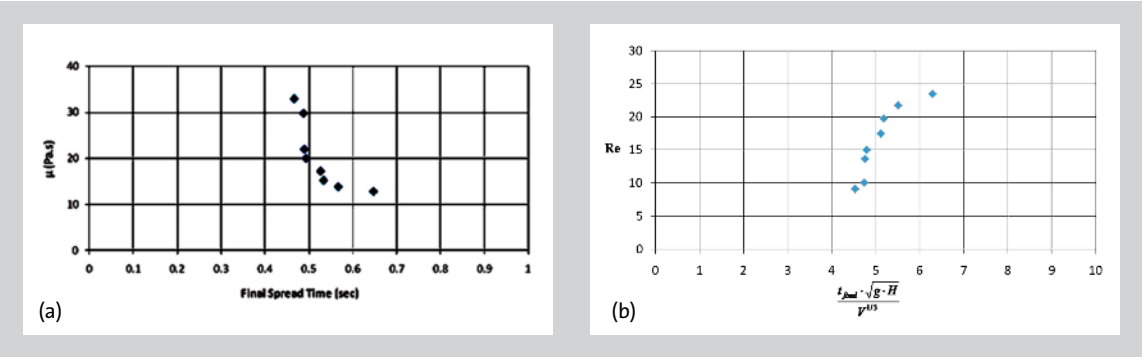

Figure 13: The dimensional (a) and non-dimensional (b) variation of the final spread versus plastic viscosity for Carbopol and cement mortars.

5 CONCLUDING REMARKS

Systematic measurements from an empirical characterisation test were performed, analysed and interpreted from a fluid mechanical approach in order to reveal the role of rheology and its connection to the empirical measurements of the slump test. Non-dimensional analysis reveals that there exist viscous and yield-stress dominated regions in the slump test flow, which need to be taken into consideration when empirical measurements are interpreted. Measurements which are representative of the viscosity would be indicative of the flowability of the tested mixture, while measurements which are representative of the yield stress of the tested fluid would be indicative of the onset of segregation. Our findings can be summarised as follows:

1. The time for a spread of 500 mm which is used as reference for measurement parameters, is rather an arbitrary choice; this is because the slump flow is experiencing both viscous and yield-stress effects in the flow extent of this spread, and thereby measurements may be representing different rheological characteristics (either viscosity or yield stress values of the tested fluid).
2. The final spread measurement is directly linked to the yield-stress of the tested fluid; the non-dimensional spread is linearly related to the non-dimensional yield stress of the fluid with a very good agreement for both the Carbopol and cement mortar mixtures. Moreover, the correlation lines appear to be parallel implying that this relation is universal. The observed shift is primarily due to the different viscosity value.
3. There are strong indications that the non-dimensional viscosity of the mixture is associated with the non-dimensional final spread as well as the non-dimensional stopping time of the slump flow. This set of experimental data suggests an exponential decay of the final spread and stopping time with viscosity; the precise relations remain to be confirmed with further experiments and simulations, which are beyond the scope of this manuscript.

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