Cement and Concrete Research 41 (2011) 292–300

Contents lists available at ScienceDirect

Cement and Concrete Research

journal homepage: http://ees.elsevier.com/CEMCON/default.asp

Influence of cement grouts composition on the rheological behaviour

Viet-Hung Nguyen [a], Sébastien Remond [b,c,*], Jean-Louis Gallias [d]

[a] Civil Engineering Faculty, University of Architecture, 196 Pasteur, District 3, Ho Chi Minh City, Vietnam
[b] Univ Lille Nord de France, F-59000 Lille, France
[c] EMDouai, MPE-GCE, F-59508 Douai, France
[d] Université de Cergy-Pontoise, L2MGC, 95000 Cergy-Pontoise, France

ARTICLE INFO

Article history:
Received 14 April 2010
Accepted 23 November 2010

Keywords:
Cement D
Admixture D
Rheology A
Grout
Herschel–Bulkley

ABSTRACT

The influence of water to cement ratio, HRWRA content and viscosity modifying admixture content on the rheological characteristics of cement grouts considered as Herschel–Bulkley fluids is studied experimentally. Results show that cement grouts without chemical admixtures and cement grouts containing only a viscosity modifying admixture present a shear-thinning behaviour with an approximately constant value for the exponent n of Herschel–Bulkley model. On the contrary, grouts containing a HRWRA content near the saturation point exhibit quasi Binghamian behaviour. The Herschel–Bulkley model describes properly the rheological behaviour of cement grouts without chemical admixtures. It can be applied correctly to grouts containing HRWRA and/or viscosity modifying admixture in a shear rate range comprised between 4 s^{-1} and 100 s^{-1} and can be used to predict satisfactorily the Marsh cone flow time of cement grouts of widely varying compositions.

1. Introduction

Cement-based grouts are widely used for filling post-tensioning ducts to protect wire strands against corrosion and to transfer stresses between the strands and concrete. To facilitate pumping and to provide full voids penetration in the duct and proper coating of steel surface, grout mixtures should be fluid enough. Moreover, after grouting, grout mixtures should not present sedimentation of cement particles or bleeding of free water filling the upper parts of post-tensioning ducts to ensure corrosion protection, stress redistribution and freeze–thaw resistance [1]. High fluidity and stability of cement grouts are also the main requested properties for diverse grouting applications including anchorage, ground treatment, rock or soil permeability reduction, concrete repair and oil well completion [2]. To ensure high fluidity, stability and adequate mechanical properties, chemical admixtures such as High Range Water Reducing Admixtures (HRWRA) and viscosity modifying admixtures (VMA) are used separately or together in grout mixes with the aim to obtain appropriate properties [3]. The systematic study of the influence of these admixtures on the rheological behaviour of cement grouts is therefore of great importance in order to improve grouting results.

Many studies on the rheological behaviour of cement-based grouts have shown that these materials are viscoplastic fluids presenting a yield stress, which must be overcome by the shear stress so that the flow takes place [2,4,5]. The rheological behaviour of the grouts can be shear-thinning type [6–8] or shear-thickening type [9,10], depending on many parameters such as solid concentration (water/cement ratio), interaction between particles, size and shape of grains … [11]. It can be described satisfactorily by the Herschel–Bulkley model [11–13] characterized by three parameters: yield stress τ_0, consistency K and exponent n which relates, in the case of simple shear, the shear stress τ to the shear rate $\dot{\gamma}$ by the following relation (Eq. (1)):

$$\begin{cases} \dot{\gamma} = 0, & \text{if } \tau < \tau_0 \\ \tau = \tau_0 + K\dot{\gamma}^n, & \text{if } \tau \geq \tau_0 \end{cases} \quad (1)$$

When $n=1$, the Herschel–Bulkley model is reduced to the Bingham model which is also used in the literature to simulate the rheological behaviour of cement grouts [5,8]. However, the Bingham model cannot take into account the nonlinearity (curvature) of flow curve of the grout, which is generally significant at low shear rate [14]. It overestimates the yield stress for the shear-thinning fluids [14] or underestimates, even gives a negative yield stress, for the shear-thickening fluids [15].

Other analytical models (Casson, de Kee, ...) have also been proposed in the literature to describe the rheological behaviour of cement grouts [16]. However, these models have no further application in the flow description of cement grouts. Until now, only the Bingham [17] and the Herschel–Bulkley models [18,19] have been used to predict the Marsh cone flow time allowing to verify the validity of these models to describe the flow of cement grouts.

The purpose of this paper is to study the influence of water to cement ratio, HRWRA and VMA contents on the rheological characteristics of cement grouts considered as Herschel–Bulkley fluids and to verify the

* Corresponding author. EMDouai, MPE-GCE, F-59508 Douai, France.
E-mail address: sebastien.remond@mines-douai.fr (S. Remond).

0008-8846/$ – see front matter © 2010 Elsevier Ltd. All rights reserved.
doi:10.1016/j.cemconres.2010.11.015