V-71 DEFORMATION FIELD OF SOLID PHASE WITHIN TAPERED PIPE IN MODEL CONCRETE FLOW

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INTRODUCTION

Inter-particle stress may be the governing factor for blocking of concrete in tapered pipes and it arises from particle collision, sliding, and re-arrangement. Evaluation of inter-particle action to predict the pumpability and blocking of fresh concrete is the aim of this research.

VISUALIZED TEST

Visualization test method[1] was adopted to obtain deformation of solid phase in solid-liquid flow in tapered pipes. The apparatus used, as shown in Fig.1, consists of a rectangular pipe section with straight and tapered portions made of transparent acrylic panel. In the test series, two different viscosities of liquid (referred as low and high viscosities), two different pumping speeds(2 cm/s and 4.3 cm/s), and three different tapered angles (tapered angle θ = 9.5, 21, 45 deg.) have been considered. After charging the polymer and particles into the pipe, the piston was moved at a constant speed while recording the particle movement by a video camera.

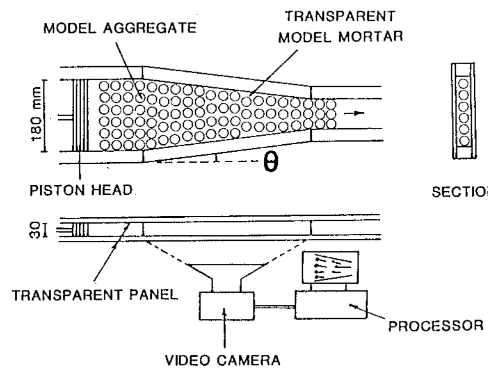

Fig. 1 Pumping apparatus for visual test

IMAGE ANALYSIS

Image processing of the visual data and evaluation of velocity field and strain field of particles are given in reference[1,2]. Using the strain components ε_x, ε_y, and ε_{xy} of particles, the deformation rate of aggregate phase can be represented with strain invariants "I" and "J" which are defined as same as in solid mechanics.

$$I = (\varepsilon_x + \varepsilon_y)/2 \quad (1)$$

$$J = \sqrt{[(\varepsilon_x - \varepsilon_y)/2]^2 + \varepsilon_{xy}^2} \quad (2)$$

STRAIN INVARIANT "J"

The invariant "J" represents the intensity of shear rate which governs the aggregate contact stress. Sectional and time average of "J" along the axis of the tapered pipe shows the deformation of aggregate phase in the tapered section influences the deformation of aggregate phase in the straight portion as well(Fig.2). This indicates that plug flow of aggregate phase does not occur near the inlet and out let of the tapered section. According to Fig.2 it seems that increase of viscosity greatly reduce the peak value of "J" which means that the increase of liquid viscosity is effective in reducing the shear deformation which leads to reduction of contact stress between particles.

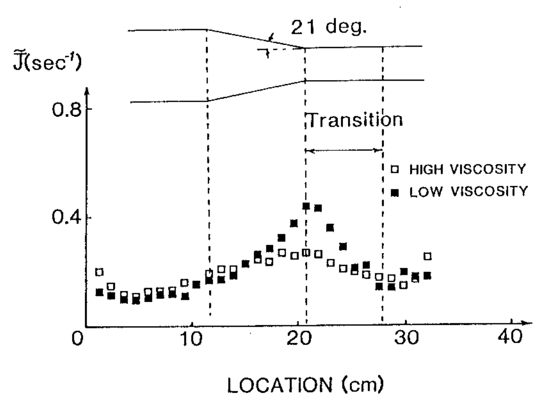

Fig. 2 Effect of liquid viscosity on "J"

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By assuming the most ideal flowing conditions of the solid phase, the following expressions can be obtained for "J" in the tapered section in terms of average velocity, tapered angle and dimension of the pipe. Referring to Fig.3, average strain at a distance x can be derived as follows.

$$\varepsilon_x = du/dx = (\bar{u}/L)2\tan\theta \quad (3)$$

where $\bar{u}$ - average velocity

Assuming the incompressibility and segregation does not take place, we have "I" which is equal to zero.

$$\varepsilon_x + \varepsilon_y = 0 \qquad \varepsilon_x = -\varepsilon_y \quad (4)$$

Assuming that the shear strain ε_{xy} is equal to zero due to symmetricity, from Eq.2 and Eq.4, we can obtain,

$$J = (\bar{u}/L)2\tan\theta \quad (5)$$

Even though Eq.5 does not represents the real conditions, the parameters $\bar{u}/L$ and $\tan\theta$ can be used to analyze the test data. Fig.4 shows the variation of "J" vs. $\bar{u}/L$ for experimental results for tapered angle of 21deg. It is shown that the "J" is linearly proportional to $\bar{u}/L$. Similar behavior was obtained for θ = 12deg. and 45deg. tapered pipes. Therefore it can be assumed that the aggregate contact occurrence is linearly proportional to $\bar{u}/L$. Fig.5 shows the effect of taper angle on the gradient(β) of the best fit line passing through experimental data of "J" vs. $\bar{u}/L$. It can be seen that the rate of "J" is linearly proportional to increment of $\tan\theta$. By considering the effect of u/L and $\tan\theta$ we have,

$$J = K_1(1 + K_2\tan\theta)\cdot\bar{u}/L \quad (6)$$

In one dimensional analysis, it can be assumed that the aggregate contact stress is proportional to $K_1(1 + K_2\tan\theta)$ and $\bar{u}/L$ if the viscosity of liquid and volume fraction is constant. Where K_1 and K_2 are constants which may depend on the volume fraction of aggregate and viscosity of liquid phase.

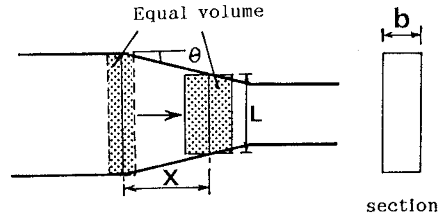

Fig. 3 Idealization of the deformation of aggregate phase

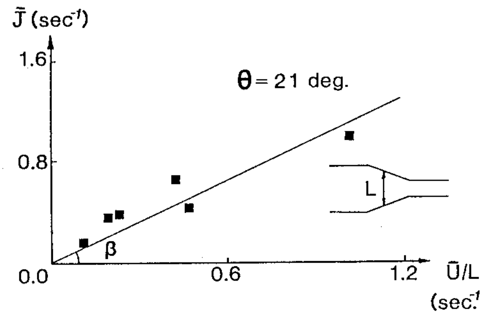

Fig. 4 Strain Invariant "J" versus $\bar{u}$/L for taper angle θ = 21 deg.

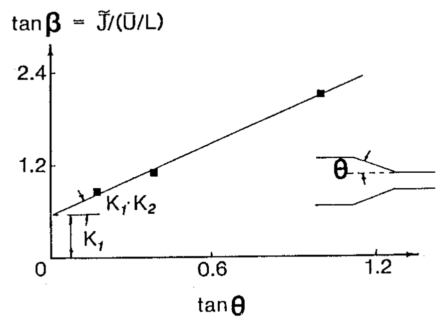

Fig. 5 Variation of $\tan\beta$ versus $\tan\theta$

CONCLUDING REMARKS

Even though it is not possible to make firm conclusions regarding the effect of the parameters considered in this study to the deformation of aggregate phase, some qualitative informations have been obtained such as the shear deformation varies linearly with $\bar{u}$/L and non-linearly varies with taper angle. In the evaluation of aggregate contact stress, which arise from collision, sliding and re-arrangement of particles, the effect of liquid velocity, taper angle, volume fraction of particles and viscosity of liquid phase have to be considered.

REFERENCES

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