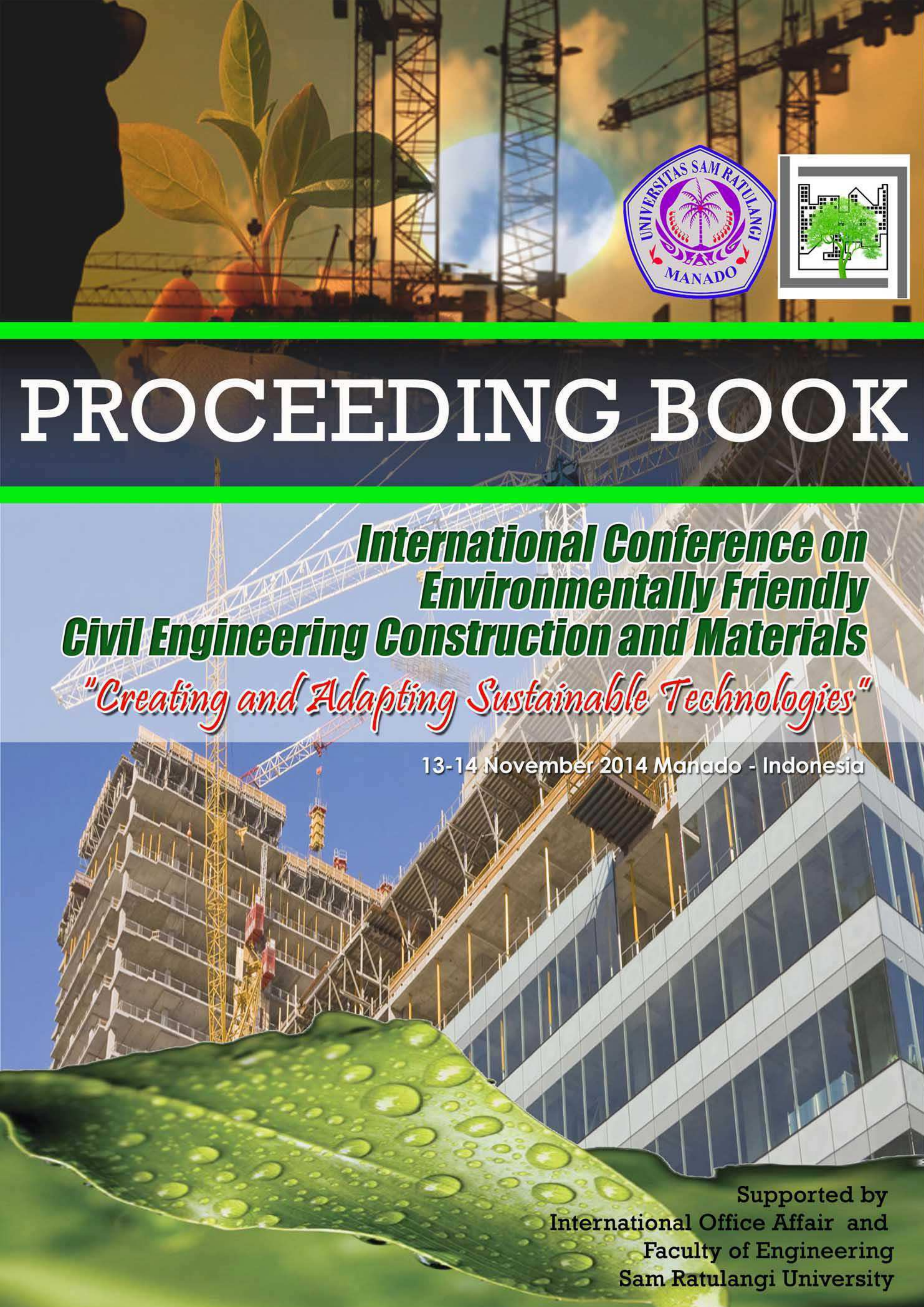

PROCEEDING BOOK

International Conference on Environmentally Friendly Civil Engineering Construction and Materials

"Creating and Adapting Sustainable Technologies"

13-14 November 2014 Manado - Indonesia

Supported by
International Office Affair and
Faculty of Engineering
Sam Ratulangi University

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PROCEEDING

EFCECM
2014

The International Conference on Environmentally Friendly Civil Engineering Construction and Materials

Creating and Adapting Sustainable Technologies

MANADO –INDONESIA
13 – 14 NOVEMBER 2014

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PREFACE

During the recent decades, environmental quality has become a main issue in most aspects of life including in construction industries. Significant progress has been made to protect the quality of environment through implementation of methods and the use of construction materials which pro the quality of environment. Construction industries, however, also significantly contribute to the environmental degradation. Carbon dioxide emission from the manufacture process of portland cement is one of main contributors to the global warming. Therefore, it is important to apply a comprehensive and sustainable approach to reduce the impact of construction industries on environmental quality. Application of methods and use of materials for civil engineering infrastructure which are environmentally friendly would be the wise solution to minimize the environmental impacts due to construction activities.

The conference has been organized to provide an opportunity to link professional and researchers to learn, share and exchange the latest method, approach and developed theories which may reduce the impact of civil engineering construction activities on environmental quality, with following objectives:

1. To provide a forum for exchange of ideas, achievements and experiences and information addressing to environmental issues among academics, researchers, engineers, manufacturers and post graduate scholars in civil engineering field.
2. To discuss and evaluate the latest methods, approaches and innovative technologies to improve environmental quality which are related to civil engineering field.
3. To increase interaction between civil engineering practice, research and education to prevent environmental degradation.

Participants of the conference included researchers, academic staffs, postgraduate students, industries and governments. The keynote speeches during the conference were presented by:

Prof. Joseph Davidovits,
President of Geopolymer Institure in French.

Prof. Vijaya Rangan,
Emiritus Professor from Curtin University, Australia.

Prof. Jun Shimada,
President of Center for Marine Environment Studies, Kumamoto University, Japan

Prof. Ashantha Goonetilleke,
Queensland University of Technology, Australia.

Prof. Djwantoro Hardjito,
Petra Christian University, Indonesia.

Prof. Ofyar Z. Tamin,
Bandung Institute of Technology, Indonesia

Prof. Tommy Ilyas,
University of Indonesia, Indonesia

Dr. Giovanni Luca Pesce,
Univeristy of Bath, United Kingdom.

The conference papers and oral presentations were divided into four major main topics as follow:

1. Structure, Geopolymer and Other Construction Materials.
2. Water Resources and Environmental Management.
3. Transportation and Urban Infrastructure.
4. Geotechnical Engineering.

Finally, the conference Organizing Committee wishes that the conference may provide beneficial scientific information to the participants and the conference proceeding readers.

Organizing Committee,

Dr. Isri Ronald Mangangka
(Chairman)

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The International Conference on Environmentally Friendly
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RHEOLOGICAL CHARACTERISTICS OF HYPERCONCENTRATED SEDIMENT-LADEN PIPE FLOW

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ABSTRACT

The characterisation of the flow of large suspended sediment loads is an area of ongoing research. This paper concerns an experimental study of the fully developed turbulent pipe flow with silt particles deposited in lower region of the river basin. The flow data include friction factor vs. Reynolds number, volumetric sediment concentration, and mean flow velocity. In addition, the rheological properties of the mudflows were investigated by using both coaxial cylinder rheometer and parallel plate one. The experimental results stressed that at high sediment concentration mudflows did not fit to the Bingham model at low shear rates, the friction factor increased with the sediment concentration which result from the viscosity increase by two to three orders magnitude.

KEYWORDS: mudflows, sediment concentration, rheological properties, viscosity

1 INTRODUCTION

Hyperconcentrated flows with high concentration of fine sediment are observed in various conditions such as mudflows, rivers basin, and tidal currents containing lagoon sediment. In particular, a large amount of sediment flows into the river, causing an increase in the number of raised river beds and a decrease in the capacity of flood control in the lower reaches. Hyperconcentrated sediment-laden flows, whose sediment concentration rises to 30% in the case of flood, is a threat to people living along the river.

Hyperconcentrated sediment-laden flows, on which a wide range of studies have been conducted, are known to have non-Newtonian properties. Qian Ning et al. used a Bingham fluid model and P. Coussot used a pseudoplastic fluid model having yield stress to study the numeric relationship of yield stress and viscosity coefficient with particle concentration and particle size distribution. Ashida et al. used a Bingham fluid model and the concept of electric double layer to evaluate bonding power between particles, and deduced expressions on yield stress and viscosity coefficient based on the bond cutting energy associated with shearing. Eto et al. studied incoherent sediment flows on the basis of conventional studies on debris flows and deduced constitutive equations from changes in Karman constant relating to sediment concentration. These studies, however, did not clarify the flow structure or resistance law of non-Newtonian fluid. In a pipe flow test, Toms found a significant drag reduction by addition of a small amount of linear high-polymer additive to solvent; this is well known as the Toms effect. In a pipe flow test using surfactant and high polymer, Munakata observed a drag reduction of as much as 70%. The present study focuses on the non-Newtonian properties of hyperconcentrated sediment-laden flows and elucidates their drag properties. Such flows are generated by using riverbed material collected in the lower reaches of the Sira River, Kumamoto Prefecture and commercially available kaolin particles. The structure of non-Newtonian fluid flows with high sediment concentration is investigated by using a high-polymer solution having viscous properties similar to those of hyperconcentrated sediment-laden flows.

2 VISCOSITY TEST

2.1 Test Material

The river sediment suspension, kaolin suspension, and high-polymer solution were subjected to viscosity measurement. The river sediment was collected as riverbed material in the lower reaches of the Sira River (278 km upstream from the estuary). The material was put through fine sieves to prepare two sets of samples (Sira River Sediment 1 and 2) having different concentrations of trace viscous particles (d<10 μm). Sira River Sediment 1 has a median particle diameter of d_{50}=21.8 μm and a viscous particle concentration of 34%, whereas Sira River Sediment 2 has a median particle diameter of d_{50}=16.4 μm and a viscous particle concentration of 44%. The particle size distributions of the samples are shown in Figures 1a and 1b. The kaolin material, whose particle size distribution is shown in Figure 1c, has a density of ρ=2.7 g/cm3 and an average particle diameter of d_{50}=5.3 μm. The particle size distributions were measured by using a laser-dispersion size distribution meter. Poly sodium acrylate (PSA) was used as the high polymer material.

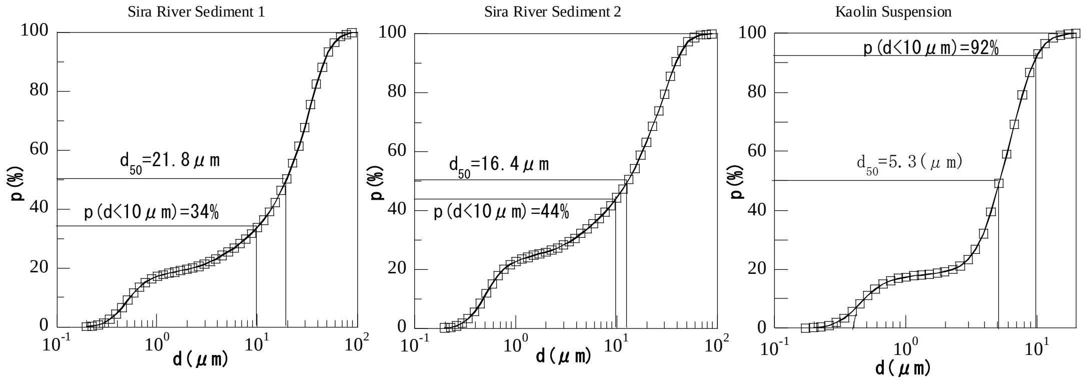


Figure 1: Particle size distributions

2.2 Test apparatus

Brookfield's DV-II+ PRO Digital Viscometer and R/S Controlled Stress Rheometer were used for the viscosity measurements. The DV-II Viscometer, a rotational, coaxial, double-cylinder viscometer, is suited for low viscosity and low shear rate measurements, whereas the R/S Rheometer, a rotational, parallel-disc viscometer, is suited for high viscosity and high shear rate measurements. The rotational viscometers were connected through adiabatic pipes to a circulation-type thermostatic tank with a precision of ±0.3^{O}C in water temperature, and sample temperature was maintained at 20^{O}C.

2.3 Test Results

The relationship between apparent viscosity coefficient and shear rate are shown in Figures 2(a), (b), and (c) for the Sira River sediment suspension, kaolin suspension, and PSA solution, respectively. In all cases, apparent viscosity coefficient decreases with increasing shear rate. Because apparent viscosity coefficient and shear rate show a linear relationship in the log-log diagrams except in the case of 20% concentration of Sira River sediment, the relationship can be approximated by the power-law model given by equation (1). This means the fluids should be dealt with as having non-Newtonian pseudoplastic (shear-thinning) characteristics. Also, viscosity increases with increasing concentrations of additives and viscous particles.

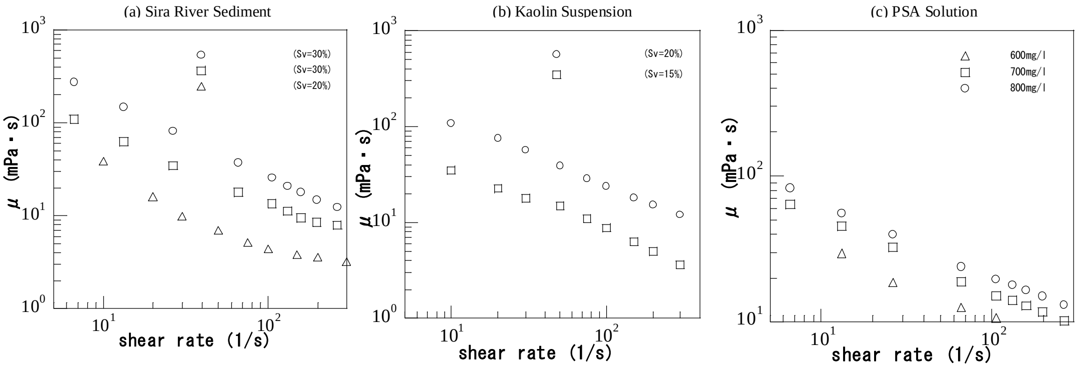


Figure 2: Relationship between apparent viscosity coefficient and shear rate

$$\tau = \eta\left(\frac{du}{dy}\right) \tag{2}$$

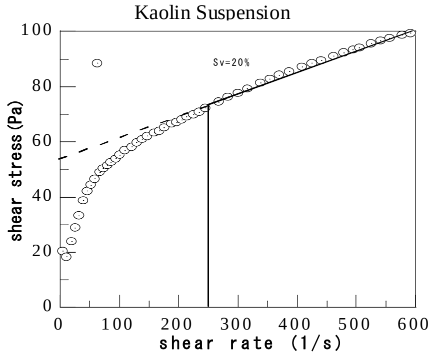
where, τ: shear stress, η: apparent viscosity coefficient; $\eta = \eta_0\left(\frac{du}{dy}\right)^{n-1}$, du/dy : shear rate

Figure 3 shows the relationship between shear stress and shear rate for the kaolin suspension of 20% in volumetric concentration. As a property of non-Newtonian fluid, the relationship can be approximated to be linear when shear rate is 250 1/s or more, thus the Bingham fluid model is applicable as shown in equation (2), but the relationship is nonlinear when shear rate is lower.

$$\tau = \tau_B + \eta\frac{du}{dy} \tag{2}$$

where, τ: shear stress, τ_B: yield stress, η: apparent viscosity coefficient, du/dy: shear rate

Figure 4 shows the dependence of apparent viscosity coefficient on shear rate for the case of 20% volumetric concentration of kaolin suspension. When shear rate is 10 1/s or less, apparent viscosity coefficient is in the range of 100 to 1000 times that of pure water. Apparent viscosity coefficient is as high as 1500 times that of pure water when shear rate is 2 1/s.



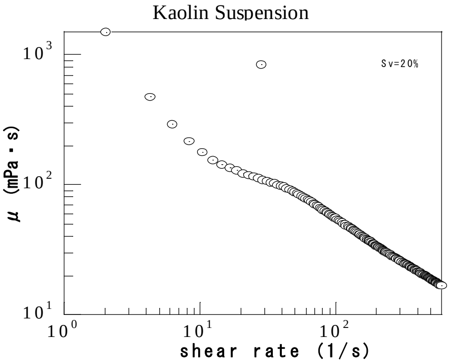


Figure 3: Relationship between shear stress and shear rate

Figure 4: Relationship between apparent viscosity and shear rate

3 PIPE FLOW TEST

Based on the viscosity properties of hyperconcentrated flows elucidated by the viscosity test, the drag properties of the flows were investigated experimentally.

3.1 Test Materials

One of the test materials is riverbed material collected at the lower reaches of the Sira River (278 km upstream from the estuary). It has a density of ρ=2.7 g/cm3 and an average particle diameter of d_{50}=44 μm. The particle size distribution of the Sira River sediment is shown in Figure 5. Another test material is the kaolin used in the viscosity test.

3.2 Test Apparatus

Figure 6 shows the outline of the equipment used for the pipe flow test. The cylindric pipe used for the test is a hydraulically-smooth, transparent, polyvinyl chloride pipe having a length of 4 m and an inner diameter of d=20 mm. An agitator was installed in the tank to avoid sedimentation and to keep constant concentration of fluid flowing into the pipe. Flow rate is regulated by the valve immediately downstream of the pump, and the stability of flow rate is confirmed periodically. To suppress the rise of suspension temperature by pumping, a thermostat was installed in the tank to keep water temperature constant; temperature variation was within $\pm 0.5^{o}$C. Friction head loss was measured with a manometer, with the lengths of measurement section l being 2000 and 500 mm in pure water and sediment-laden flows, respectively.

3.3 Test Method

The dependence of coefficient of friction loss on sediment concentration was investigated by increasing concentration stepwise while keeping flow rate constant, and the dependence of coefficient of friction loss on flow rate was investigated by increasing flow rate stepwise while keeping concentration constant. Coefficient of friction loss f is given by

$$f = h_f \frac{D}{l} \frac{2g}{v^2} \tag{3}$$

where, h_f: friction head loss, D: pipe diameter, v: average cross-sectional flow velocity, g: gravitational acceleration, l: length of measurement section.

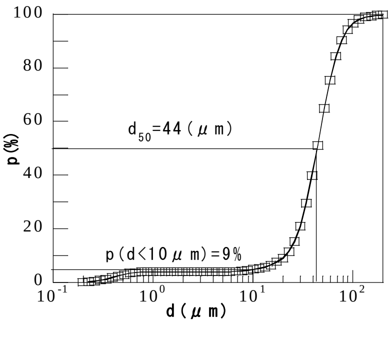


Figure 5: Size frequency

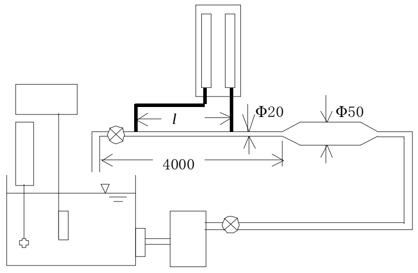


Figure 6: Pipe flow system

3.4 Test Results

Figure 7 shows the relationship between coefficient of friction loss and sediment concentration for constant average cross-sectional flow velocity. In both the Sira River sediment and kaolin, coefficient of friction loss increases linearly with sediment concentration within the concentration rage of up to 13%.

At a concentration of 10%, coefficients of friction loss are 1.30 and 1.28 times that of pure water in the Sira River sediment and kaolin, respectively; the Sira River sediment shows a slightly higher value. The results are in agreement with Imamoto and Otoshi ,who found that coefficient of friction loss increased with concentration in open channel smooth flows. Average cross-sectional flow velocities were set to 247.3 and 236.5 cm/s for the Sira River sediment and kaolin, respectively, and no sedimentation was observed on the pipe bottom.

Figure 8 shows the relationship between coefficient of friction loss and average cross-sectional flow velocity for constant volumetric concentration. volumetric concentrations were set to 13.7% and 9.5% for the Sira River sediment and 13.0% and 9.7% for the kaolin. Although the kaolin data has notable variation, coefficient of friction loss generally decreases with increasing flow velocity. As is the case with Figure 7, the Sira River sediment shows slightly higher values. The coefficients of friction loss in flows containing the kaolin or Sira River sediment are greater than those in pure-water flows.

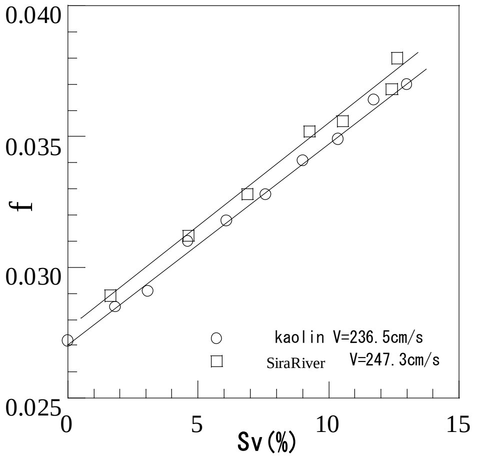


Figure 7: Friction loss coefficient and Sediment Concentration

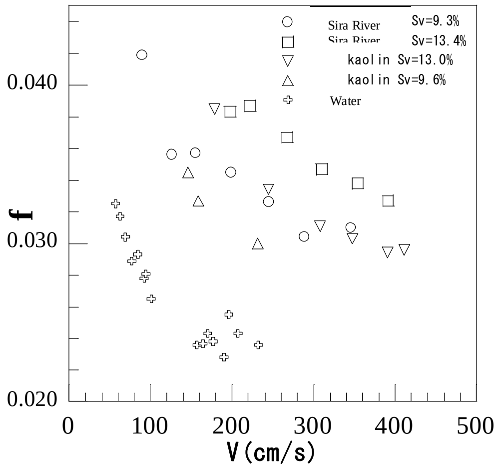


Figure 8: Friction loss coefficient and flow velocity

To consider the resistance law of hyperconcentrated sediment-laden flows, Reynolds number must be calculated. Because viscosity coefficient depends on shear rate in hyperconcentrated sediment-laden flows, wall shear rate was adopted as a representative value in this study as shown in equation (4). Wall shear rate γw was obtained from the Rabinowitsch's equation, which is highly compatible with non-Newtonian fluid flows in pipes.

$$\gamma_w = \frac{3}{4}\frac{4Q}{\pi R^3} + \frac{\tau_w}{4}\frac{d}{d\tau_w}\left(\frac{4Q}{\pi R^3}\right) \qquad (4)$$

where, Q, R, and τw are flow rate, pipe diameter, and wall shear rate, respectively. Figure 9 shows the relationship between Reynolds number, obtained from viscosity coefficient μ corresponding to each shear rate, and coefficient of friction loss f. The experimental precision is confirmed by the fact that pure water data complies with the Blasius 1/4 power law. When wall shear rate is used, coefficient of friction loss in kaolin suspension flow is greater than that in pure water flow, and Reynolds number in kaolin suspension flow is smaller than that in pure water flow for the same flow rate (245 cm/s). The increase in coefficient of friction loss with sediment concentration shown in Figure 7 is therefore ascribed to increases in viscosity coefficient and kinematic viscosity and decreases in Reynolds number introduced by the sediment. The effect of drag reduction by high-polymer addition is found at viscosity values a few times higher than those of water. In the present test, viscosity values are 10 to 1000 times higher than those of water, implying that increased viscosity effect at low shear rates contributed to drag increase.

4 CONCLUSION

The drag and viscosity properties of hyperconcentrated sediment-laden flows were investigate by using silty riverbed material collected in the lower reaches of the Sira River, kaolin clay, and high polymer. The results obtained are summarized as follows.

1) Coefficient of friction loss increased with increasing sediment concentration in both the Sira River sediment and kaolin. At a concentration of 10%, coefficients of friction loss are 1.30 and 1.28 times that of pure water in the Sira River sediment and kaolin, respectively; the Sira River sediment shows a slightly higher value.

2) The hyperconcentrated sediment-laden flow and high-polymer solution have non-Newtonian properties. The flow can be approximated by the Bingham fluid model when shear rate is 250 1/s or more. Below this value, apparent viscosity coefficient μ is strongly dependent on shear rate, so that the power law model is applicable.

3) An explanation for the increased coefficient of friction loss in hyperconcentrated sediment-laden pipe flows is that viscosity coefficient μ is increased and Reynolds number is decreased by the presence of hyperconcentrated sediment.

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