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ACCUMULATION OF FRAZIL SLUSH AND VELOCITY DISTRIBUTION UNDER THE ICE COVER

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SYNOPSIS

During winter period the cold air causes a huge frazil production in a river. For the hydro power stations in cold region the intake is very susceptible to blockage due to adhesion of frazil ice on it. HOKKAIDO EPCO., therefore, set an ice control structure which is a combination of woodenfence boom and gabions in a small river for effective diversion of water sources and observed hydraulic and meteorological conditions including water temperatures. During this field test, frazil slush clogged the fence boom and changed it to an ice dam, which raised water level upstream the fence boom and formed a pool with an ice cover, where was observed frazil slush accumulation. As a result, the power station did not need to carry out deicing work of its intake during the test, which were normally required several times a year. Described herein are formation process of frazil slush accumulation and velocity distribution under the ice cover.

INTRODUCTION

The rivers in Hokkaido, which is situated in a snowy and cold region, contain a large quantity of flowing flazil slush. The frazil of the active state has a character which will adhere to almost all the structure in the water, thus causing serious problems for hydro power stations. Last three years, we set the ice control structure which was intended to form an artificial ice dam in the Penkeniuppu River (catchment area A=159km ^{2} ,approximately 20 km long from the origin to the intake), where the Niuppugawa Power Station (HOKKAIDO EPCO.)is located, to prevent influx of frazil slush into the intake. Together with observation of hydraulic and meteorological conditions,the development of ice cover and the accumulation of frazil slush under the ice cover were measured upstream the ice control structure. In early March, we also observed new phenomena, the discharge shows a daily oscillation through field survey in the Penkeniuppu River.

The purpose of this report is to describe field tests aimed at using the ice control structure to form pool and ice cover. This paper is also described active or passive state of water temperatures causing by daily oscillation of the river discharge.

ICE CONTROL STRUCTURE AGAINST INFLUX OF FRAZIL SLUSH AND FORMATION PROCESS OF ICE COVER

The Niuppugawa Power Station is a small scale run-of-river power station (maximum output is 1,850 kW at a maximum available discharge of 7.13m^3/s) of which penstock used to suffer blockage from frazil slush three times. Therefore we installed an ice control structure with fence boom to prevent influx of frazil slush approximately 310 meters upstream the dam, as shown in Figure 1. In a small pool (called "the upper pool") which was formed upstream the ice control structure and another pool (called "the lower pool") in the dam of the power station, measurements were taken about ratio of freezing width against total width of the river (ratio of ice coverage), elevation of ice surface and thickness of ice cover at the traverse lines provided at every 20 meters along the river. Figure 2 shows vertical change in elevation of ice surface of the upper pool. According to this figure, the elevation of ice surface has changed owing to increase and decrease of frazil slush under the ice cover, which reached the highest level from January 31 to February 7 during the winter period. Because frazil slush under the ice cover can be fully accumulated, the buoyancy force can be substantial.

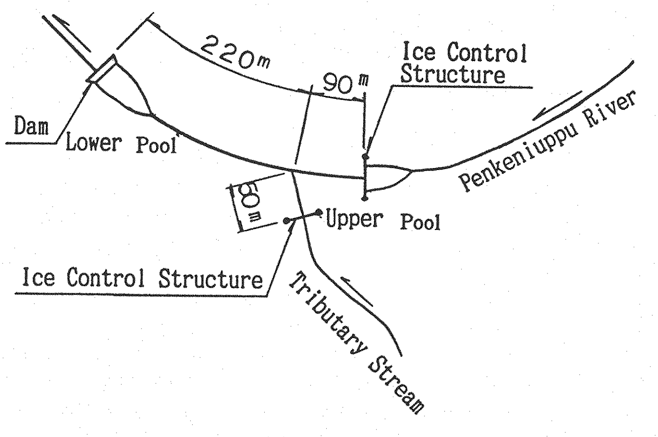

Fig.1 Location of installed ice control structures

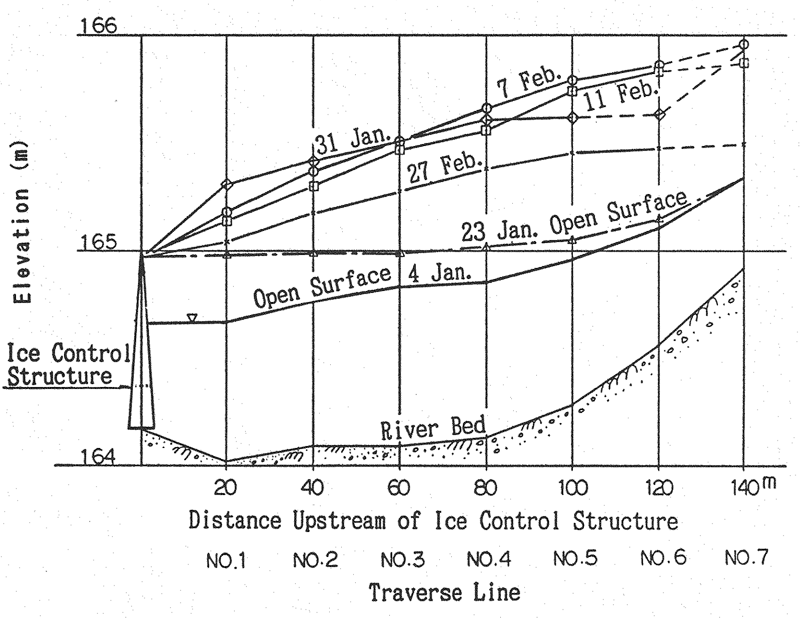

Fig.2 Ice surface profiles in the upper pool, 1992

Figure 3(a)and(b) show the air and the water temperatures at the intake of 1992. The water temperatures were measured with platinum resistance thermometer which had a resolution of 0.02 ℃ . The river temperatures below the freezing point is called "active state" and those above the freezing point "passive state". To estimate the thermal condition of river by the day , the supercooling index was devised which depict the daily hours of the active state and the passive state, as shown Figure 3(c). Active state of water temperatures from late January to early February accelerated a freezing of the river and growth of frazil, which corresponds to period when the highest elevation of ice surface was recorded as shown Figure 2, followed decreasing frazil in quantity at passive state of water temperatures from mid February to early March.

ACCUMULATION OF FRAZIL SLUSH AND VELOCITY DISTRIBUTION UNDER THE ICE COVER

To study the formation process of an ice cover upstream the ice control structure, we measured velocity distributions under the ice cover and ice thickness along the traverse lines of NO.1 and NO.3 of the upper pool four times from December 1992 to February 26, 1993, as shown Figure 4. Both the thickness of ice cover and the formation of frazil slush accumulation had complexly changed at every measurement. Referring to transition of Figure 4, it is assumed that frazil slush firstly adhered to ice cover at the middle part of the river and then progressed toward river bed under the ice cover (see Figure 4b). Increasing and decreasing of frazil slush under the ice cover raise the elevation of ice surface up and down,which reached the maximum on early February as shown Figure 2. Consequently, main current was distributed to both shores and river water was forced to flow in narrow space among ice cover, flazil slush and river bed.

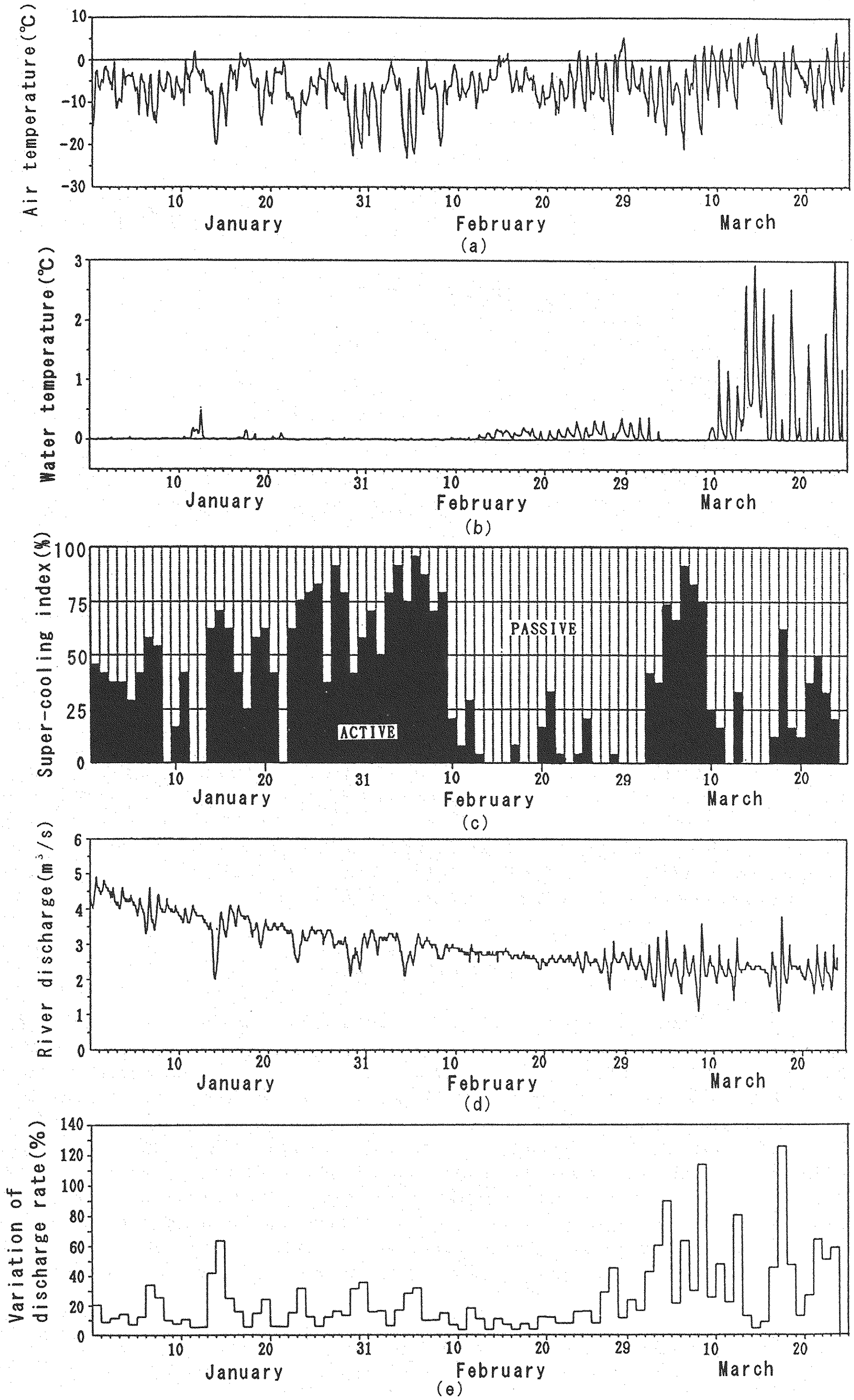

Fig.3 Time history of, air temperature(a), water temperature(b), super-cooling index(c), river discharge(d), variation of discharge rate(e), 1992

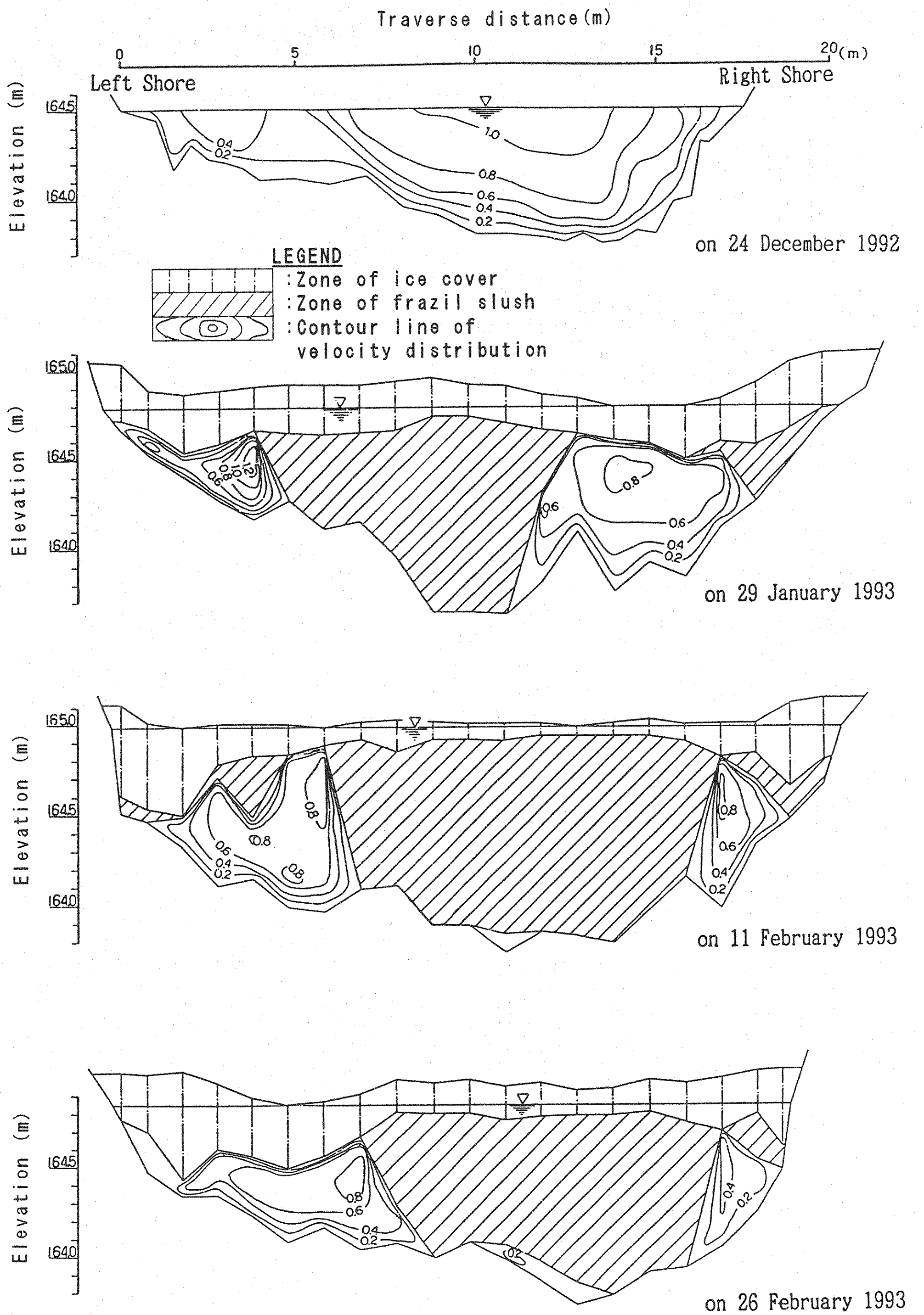

Fig.4(a) Velocity distribution and accumulation of frazil slush under the ice cover at NO.1 traverse line in the upper pool

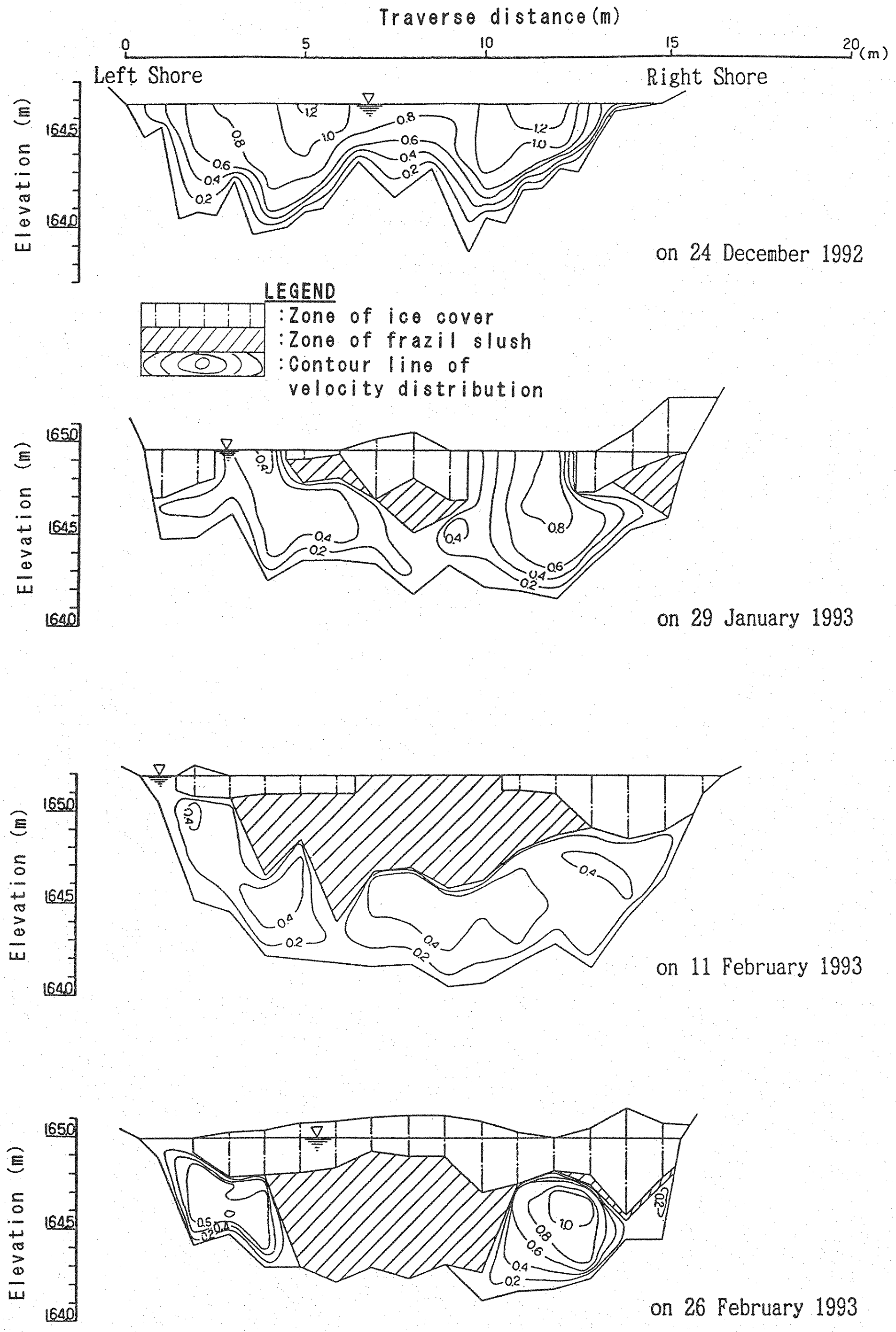

Fig.4(b) Velocity distribution and accumulation of frazil slush under the ice cover at NO.3 traverse line in the upper pool

GENERATION OF FRAZIL SLUSH AND CHANGE OF THE RIVER DISCHARGE

The river discharge calculated back from hourly output of the Niuppugawa Power Station and the variation of discharge rate during a day($(Q_{max}-Q_{min})/Q_{ave}$) are shown in Figure 3(d)and(e). The daily periodical change of discharge was relatively larger on January when the shore ice developed gradually and on March when the ice cover began to break up than that on February while the upper pool was entirely covered with ice. It can be explained by that both active state and passive state of the water temperatures were coming out during a day. That is to say, river discharge were to decrease since frazil had generated and adhered to ice cover to be accumulated during the active state,whereas river discharge were to increase as frazil slush released and flew during the passive state in a day. Particularly on early March, active frazil slush develops anchor ice dams on the river bed and forms so called step-pools. The step-pool plays a roll of a weir to rise the water level on the upstream side causing by daily oscillation of the river discharge. We have to pay attention that the relationship between discharge and water surface elevation is not always exact in a cold region river.

CONCLUSIONS

The results obtained from the observations are as follows:

1) Inflow of frazil slush to the intake decreased considerably and there was no need for deicing work of the intake for three years after having installed ice control structure.
2) A condition of frazil slush production depends on whether river water temperature is active state or passive state.
3) It turns out that velocity distribution under the ice cover complexly changed in shallow river.
4) Frazil slush under the ice cover repeatedly accumulate or decrease during the day as well as through the winter period. In particular, daily oscillation of the river discharge was quite large on early March because anchor ice dams were formed naturally in the free water flow.

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