Experimental Consideration for Countermeasures Using Multi-drop Structures in Supercritical Flow

Hiroaki TSUNAKAWA[1], Toshiharu ARISAWA[1], Haruki WATABE[2*], Tsuyoshi IKESHIMA[2], Yotaro NISHI[2], Yohei NAGAREKAWA[2], Satoru MATSUDA[2], Takashi NAKAYAMA[3], Takahiro ITOH[2] and Takahisa MIZUYAMA[4]

[1] Tajimi office of Sabo and National Highway, Ministry of Land, Infrastructure, Transport and Tourism, Japan
[2] Nippon Koei Co., Ltd., Japan
[3] Tamano Consultants Co., Ltd, Japan
[4] National Graduate Institute for Policy Studies (GRIPS), Tokyo, Japan
*Corresponding author. E-mail: a6809@n-koei.co.jp

INTRODUCTION

Some researches were conducted experimentally for planning of channel works such as multi-drop structures (e.g., Ashida et. al., 1975; Mizuyama et. al., 1989). Those researches pointed out several problems for multi-drop structure in supercritical flow. One is local scoring due to the drop flow, and another is increasing of flow depth due to the shock waves caused by multi-drop structure and is increasing of velocity at downstream end (e.g., Mizuyama et. al., 1989). In present study, characteristics of shock waves and countermeasures using multi-drop structure in a steep slope channel are discussed experimentally in supercritical flow. Shock waves yielded at side bank of multi-drop structure cause increasing of flow depth at side or center of the channel. Stair-type's dissipater can be effective at downstream of multi-drop structures for shock waves.

EXPERIMENTAL CONDITIONS

Figure 1 shows longitudinal rigid bed profiles for hydraulic model test flume, and bed slope increase gradually from 5.7° to 7.5° as decreasing of longitudinal distance. Model scale is specified as 1/100, and Froude similarity is applied for flume tests. Table 1 shows experimental runs in supercritical flows. Flow discharge is 100 m^3/s in steady flow as full capacity of cross section in uniform flow. The effects of stair type's dissipater installed in just downstream of multi-drop structure are compared with Run 1 and Run 2. Manning type's bed roughness is 0.040 m$^{-1/3}$s, and the normal flow depth is 1.38 m for flow discharge, Q, of 100 m^3/s. Training channel in multi-drop structure is trapezoid in cross section, and bed and free surface width are calculated as 8.00 m and 9.38 m (in case of Q = 100 m^3/s), respectively, at full capacity of a cross section in uniform flow conditions.

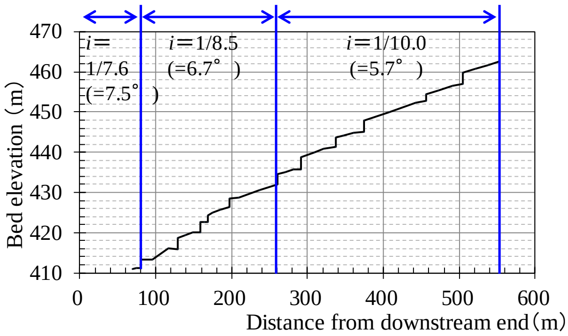

Fig.1 Longitudinal bed profile of the flume

Table 1 Experimental runs

Run No.	Flow discharge (m^3/s)	Countermeasure for shock wave
1	100	Without stair type's dissipater
2	100	Stair type's dissipater

SHOCK WAVES IN SUPERCRITICAL FLOW

Figure 2 shows flow patterns in Run 1 (without stairs), and over flow occurs at right side bank of multi-drop structure. Shock waves yielded at side bank are transported downstream, and over flow is caused by increasing of flow depth at side bank due to the concentration of shock waves (**Fig.3**). There are expansion and contraction sections at downstream of ground sill, and it also causes the increasing of flow depth because of long path of shock waves. **Figure 4** shows flow patterns in Run 2 (with stairs). Stair-type's dissipater is installed at just downstream of ground sill, and it also makes expansion and contraction sections be straight shape in plan view. **Figure 5** shows longitudinal free surface and flow depth profiles in Run 1 and Run 2, and free surface is measured at center of cross section of the training channel. Stair-type's dissipater can have roles for smoothing of longitudinal and transverse free surface profiles in comparison to Run 1 (**Fig.3**, **Fig.5**). If the space for stairs can be prepared just downstream of the drop considering flow magnitude, the stair-type's dissipater might be one of effective structures for flow smoothing because flow area is not reduced there.

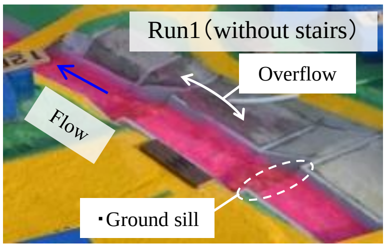

Fig.2 Flow patterns in Run 1

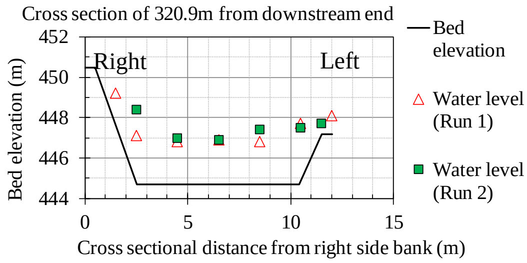

Fig.3 Cross sectional free surface distributions in Run 1 and Run 2

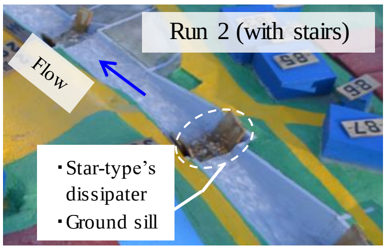

Fig.4 Flow patterns in Run 2

CONCLUSIONS

Hydraulic model tests were conducted to discuss flow characteristics of shock waves and countermeasures for multi-drop structures. Concentration of shock waves at outer bank and plain shape changes such as contraction and expansion sections near the groundsill cause increasing of flow depth, and result in overflow at the outer bank. It is better for flow smoothing to set stair-type's dissipater just downstream of drop structure. The knowledge can be included for new design and tools for multi-drop structure in a training channel with steep slope.

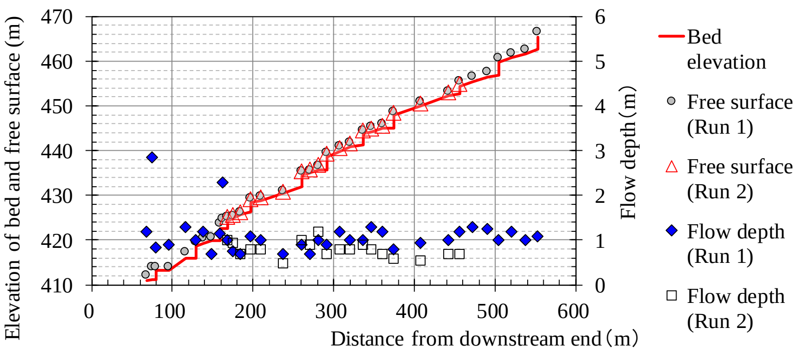

Fig.5 Longitudinal free surface and flow depth profiles in Run 1 and Run 2

REFERENCES

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Keywords: Shock wave, Multi-drop structures, Supercritical flow, Stair-type's dissipater, Hydraulic model tests