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Model Law Research on Rainfall Intensity in Spray Atomization Due to Flood Discharge

MODEL LAW RESERCH ON RAINFALL INTENSITY IN SPRAY ATOMIZATION DUE TO FLOOD DISCHARGE

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ABSTRACT

When large dam discharging flood, the water spray will cause heavy rainfall and density fog in downstream, due to huge turbulence and its collision into the downstream water body. Along with the dam getting higher, this phenomenon gained more emphasise for its influence on dam operation getting larger. There is a growing research interest on that in China, when more and more high dam constructed in the west south region. Among the research methodology, physical model research is very important to predict the prototype spray atomisation, however, the model law research remains controversial. In this paper, the model law on rainfall intensity caused by water spray is further explored through the prototype experiment and model research, and the new fitting formula on that is given by the raindrop spectrum analysis.

Keywords: water turbulence;spray atomization; model law; rainfall intensity; frequency-dominate raindrops;force-dominate raindrops;

1. INTRODUCTION

Affected by continuously changing wall surface and air friction, the high-speed water flow is strongly turbulent and aerated, when high dam discharging flood water. Small part of water body gradually loses stability, disengages from main flow and smashes into water drops. Then, the aerated jet flow fall down and collide into waterbody downstream. The spray water caused by collision, as well as water drops, splash and sprinkle in the downstream and form huge intensity rainfall. Some of tiny water drops float in the air and come into being fog flow.

This discontinuous two-phase flow phenomena caused by water turbulence and collision are called flood spray atomization in Chinese academia of hydraulics. The spray atomization phenomena when J dam(in China) discharging flood is shown in Figure.1.

Fig.1 Spray Atomization Phenomena when J Dam Discharging Flood

The practice shows, the flood spray atomization appeared in large water conservancy project have much more threat and damage on dam architecture and shore slope downstream than conventional nature rainfall, for its tremendous intensity and enormous scope. As the present research result, the influences on project by flood spray atomization are nearly negative. The huge rainfall and strong fog bring by it always result in the collapse of shore slope (such as Er'Tan project in China), shutdown of power generation for transformer problem by strong fog (such as HuangLongTan dam in China), traffic halt of road approach to dam and plant (such as DongFeng project in China),and influence on daily work and life of people near the downstream of dam, some of them are forced to move to other places (such as ZaXi dam in China) .

With more and more high dams built in narrow valley in the west of China and more cases emerged , that flood spray atomization affecting the operation of dam and plant, this phenomena began to gain wide recognition by academia, as an engineering and environmental issue. In China, the realated researches began in 1980s and the issues of flood spray atomization were listed in the top 7 engineering hydraulics problems. The flood atomization in Er'Tan plant and Three Gorges project are studied in this period and achieve some results. At present, researches on flood atomization are basically carried on in three ways, namely prototype survey, physical model test and numerical analysis. Among of them, physical model test gained much more attention for the intuitionistic result and quantificational description on this issue. Nevertheless, the model law problem is controversial in academia.

According to the result of prototype observation, the flood atomization brings rainfall and fog flow. Howere, as the limit of model scale, it is very difficult to simulate the fog flow in prototype. Or even it can be, the precision hardly be ensured for a mass of influence factors. Based on this, the present physical model is limited in research on the intensity of rainfall(mm/s) .According to Froude's simulated rule, the scale of rainfall intensity (Rr) and the scale of physical model should obey the following relationship: $Rr = Lr^{0.5}$, but result of test differ from this.

Cai gong-cun(1995) once conducted an investigation in food spray atomization of Wu Jiang Du project and achieve the model law with simple form. That is $Rr= Lr^{1.53}$.

From 2002 to 2006, researchers in Yangtze River scientific research institute did lots of research on flood spray atomization, with the funding of Institute Dean and Minstry of finnance people's republic of China.. The main research results are shown in this paper.

2. Research and measure methodology

The reserch method is to integrate the prototype survey with a series of corresponding model tests.Firstly, the prototype survey tests on rainfall intensity of J dam were made in 2003. Then a series of model tests with different scales were carried on the basis of the prototype survey data. After compareing prototype survey data with model test data, the model law of rainfall intensity was researched and the fitting formula was presented.

The prototype rianfall in different location were caputred by the automatic rain colleter.The model rianfall were mesured by the raindrop spectrum system, which are wildly used in meteorological measurement,using special filter paper (need to calibrate) to collect raindrops stain, and scanning images into vectorization, then analysising data with special data-processing program.This data collecting and analysis system are mainly including computers, scanners, measuring board, paper, data-processing program and printers.(see in Fig.2). The calibration curve between the diameters of real riandrops and the stains in the filter paper is seen in Fig.3. Where raindrop spectrum are not suitable to collect the rainfall,for example when they are too huge, the isotope measurer(see Fig.4) will be used.

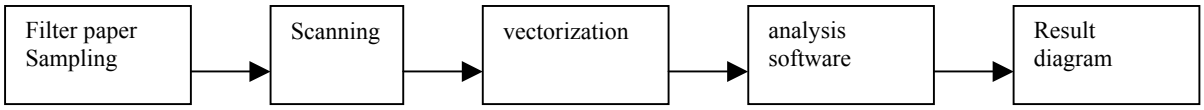

Fig.2 The Flow Chart of Data Collecting and Analysis System

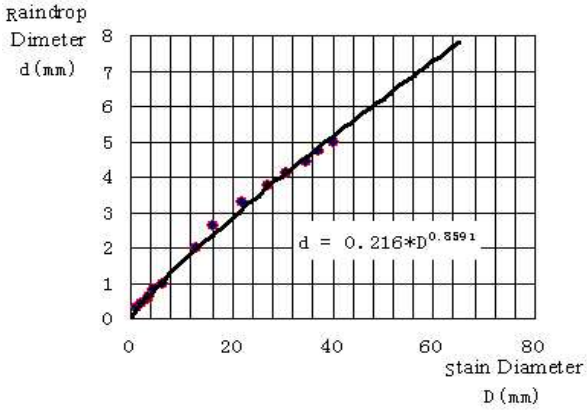

Fig.3 The Calibration Curve

Fig.4 The Isotope Measurer

3. DATA ANALYSIS

3.1 Rainfall Intensity Analysis

The intensity of prototype and model(Lr=80) rianfall are both listed in the Table.1. General speaking, the model law research is to looking for the direct relationship betweem these two figures. While compared these two figures in the traditional exponential function, the exponential n has a big rang from 1.23 to 1.78, which is shown there is no very certain direct relationship between the prototype and model rianfall intensity,see in Table.1.

Table.1.The Rainfall Intensity Values of Prototype and Model and their Relationship in Exponential Function

Test point	Model value R_m (mm/h)	Prototype value R_p (mm/h)	$n=\log_{80}(R_p/ R_m)$
1	0.082	33.10	1.37
2	0.62	354.10	1.45
3	0.82	1030.00	1.63
4	0.68	578.90	1.54
5	0.92	2226.00	1.78
6	0.21	54.00	1.27
7	1.67	396.00	1.25
8	0.86	928.00	1.59
9	0.008	5.70	1.50
10	2.21	480.00	1.23
11	0.035	60.00	1.70
12	0.046	53.30	1.61
13	1.07	460.00	1.38
14	1.60	560.00	1.34
15	0.072	106.70	1.67

3.2 Raindrop Spectrum Analysis

Raindrop spectrum analysis is to research on components of rain drops. The result shows, rain drops of each measure point are basically composed of two types raindrop: the smaller sized but larger number of raindrops and bigger sized but smaller number of raindrops. (Shown in Fig.5).The research also discovered that the frequency of smaller-size raindrops accounting for almost 70 ~ 85% of the entire composing of the raindrop, but due to the small size, the contribution of single particle to the rainfall intensity is very small. Conversely, the contribution of bigger-size raindrops to rainfall intensity is not low for their big size, even though their frequency is much smaller. To facilitate further analysis, smaller-size raindrops are called frequency-dominate raindrops and the bigger-size raindrops are called force-dominate raindrops.

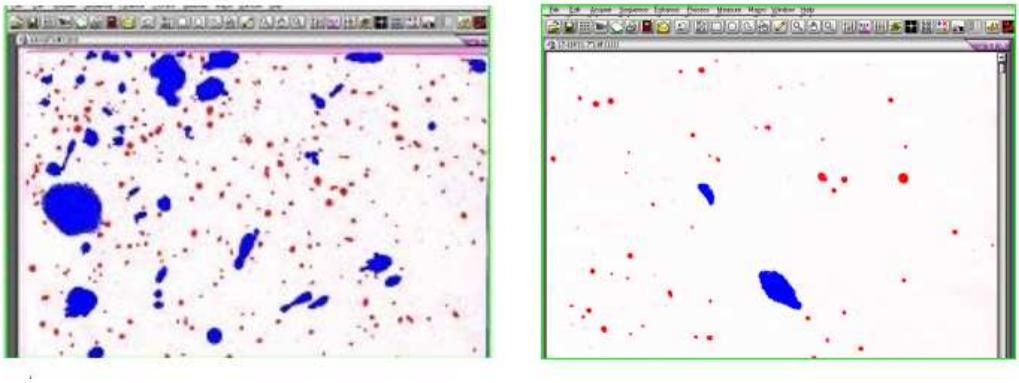

Fig.5 Two typical raindrop spectrums

The results of raindrop spectrum analysis also shows that the percentage of frequency-dominated raindrops are increasing with the distance to the region where the jet flow into downstream. And the percentage of force-dominated raindrops is just on the contrary. This means, when jet flow enter the river, the bigger-size raindrops land near the region where jet flow into downstream, by the gravitational influence. And smaller-size raindrops float further and wilder, influencing by buoyancy lift and wind.

4. Result and discussions

The frequency-dominated raindrops and force-dominated raindrops, two parts of rainfall intensity, have different factors in the process of flood atomization. The former are mainly influence by the gravity, but the factors of the latter are more complicated. Besides the influence of gravity and valley wind, the surface tension and air buoyancy can not be ignored. Therefore, this two parts of rainfall intensity should meet different model law, and the model law of rainfall intensity could be the linear combination. By the analysis on lots of original model and prototype data, the formula was fit as follows:

$$R_{mp} = R_{mf} \times L_r^{1.65} + R_{mg} \times L_r^{1.2} \qquad (1)$$

Where: R_{mp} – rainfall intensity of prototype via model conversion，mm/h；

R_{mf} – intensentity of frequency-dominated raindrops mm/h；

R_{mg} – intensentity of force-dominated raindrops，mm/h；

L_r – model scale.

The rainfall intensity of prototype via model conversion （R_{mp})are preferablely matched with the prototype data(R_p),which shown in Fig.6.

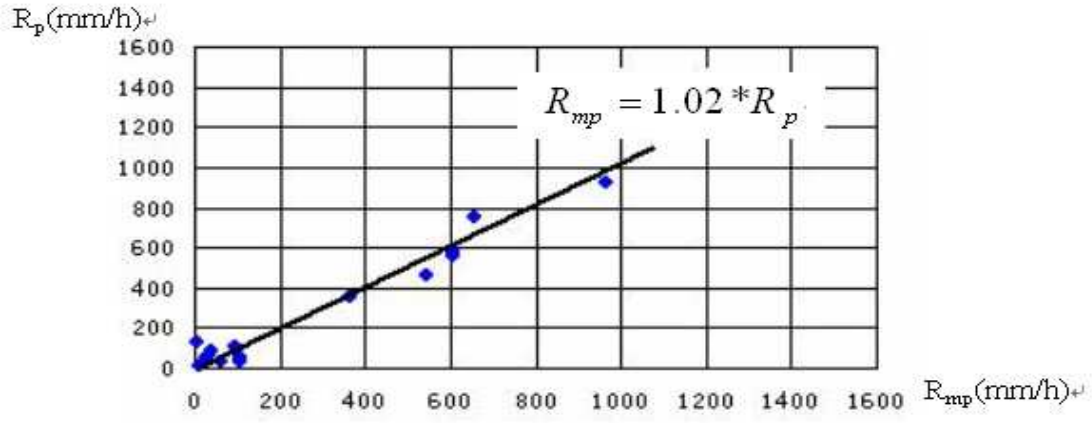

Fig.6 The Relationship between R_{mp} and R_p

5. Conclusion

Through the prototype and model research on rainfall in flood spray atomization, it is shown that the intensity of rainfall has no direct relationship between the prototype and model values. Otherwise, on the basis of raindrop spectrum analysis, it is discovered there has two different riandrops which demonstrate different contribution to the rainfall intensity. And this lead to a new relationship between prototype rainfall intensity and model one. After a series of models research, the new model law on rainfall intensity are presented in this paper. And with this model law, flood spray atomization of GouPiTan dam is researched by physical model(Lr=1:55)and the reseach results guided the slope defence design in this project.

ACKNOWLEDGMENTS

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TECHNICAL CONTRIBUTIONS

Compound Channel