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LOAD RESISTANCE APPROACH FOR RISK ANALYSIS IN NATURAL RIVERS

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INTRODUCTION:

This paper is a part of the method of risk analysis to flood problems which offers the possibility of integrating hydrology and hydraulics in a systematic design concept.Stochastic or uncertain quantities were classified in two groups. These are the hydrological input as load and the capacity of the channel section to resist it.

THE LOAD-RESISTANCE RELIABILITY METHOD:

Design based on reliability theory allows to account for distributed variables that influence the performance of the structure. The entire set of these variables is divided into two groups: load variables(s) and resistance variables(r). Failure occurs when the load exceeds the resistance at an instance. Accordingly, s and r form a joint probability distribution $f_{sr}(s,r)$. The probability of failure P_f, is the part of the joint distribution which lies below the line s = r. P_f can be calculated by integrating over $f_{sr}(s,r)$ in the r < s area as

$$P_f = P\{s > r\} = \int_0^{\infty}\int_0^{s} f_{sr}(s,r)\,\mathrm{dr}\,\mathrm{ds} \tag{1}$$

In the case of stochastic independence, P_f is determined via marginal distributions fr(r) and fs(s) of r and s and the so called Freudenthal integral

$$P_f = \int_0^{\infty} f_s(s)F_r(s)\,\mathrm{ds} = 1 - \int_0^{\infty} f_r(r)F_s(r)\,\mathrm{dr} \tag{2}$$

If s and r are correlated P_f must be found by simulation.

ZONE OF STUDY:

The zone of study is a 13.0 km reach of Kinu river staring from the 45.0 km upstream of the Tone river confluence to the 57 km reach. For this zone the cross sectional data at a pitch of 0.5 km was used for the simulation purpose.

ONE DIMENSIONAL STEADY FLOW MODEL:

The gradually varied flow equations are used to develop the one dimensional steady flow model. The standard step method [Chaudhry (1993)] is used for tracing water surface profile. The model is capable of handling the natural cross sections of any arbitrary geometry and can also handle the depth wise variation of Manning's roughness coefficient.
Independent values of Manning's roughness coefficient (n) is specified for each location of available cross section. This value was used as a base value and the model has provision to consider the variation of n with water level stage about this base value differently for each location. The following example is added to facilitate better understanding.

EXAMPLE:

A study case is illustrated to represent the method in brief. The load is the naturally varying discharge that the channel conveys over time. This is mathematically generated as a normally distributed random numbers. The mean is 5000 m^3/s which is 5% less than the 1/100 probabilistic design flood discharge. 100 random numbers of load has coefficient of variation of 0.15. The one dimensional simulation was carried out 100 times - one for each of the input load case. The downstream depth of flow was kept constant for each run. The water level

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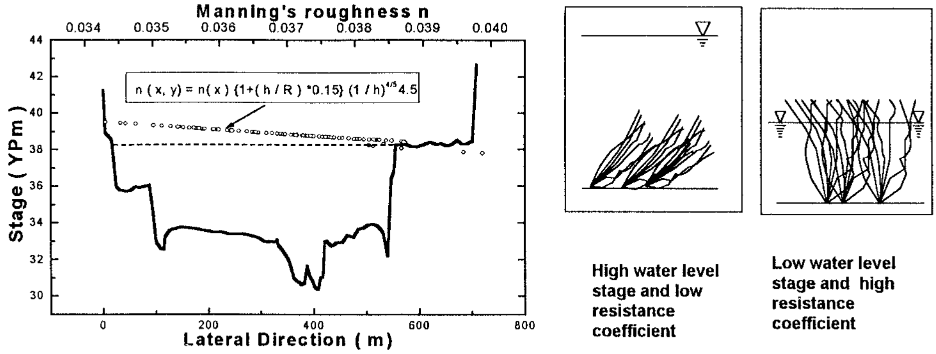

Fig. 1 Cross-section and variation of Manning's n

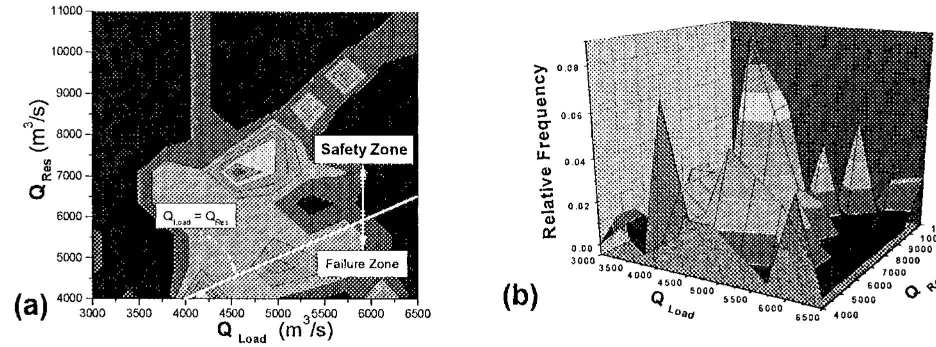

Fig. 2 Joint probability diagram of Q_{Load} and Q_{Res} shown as (a) contour plot and (b) surface plot

stage obtained as a result of the simulation is used to calculate the corresponding resistance of the channel. Manning's formula is assumed to be applicable. As mentioned before, Manning's n was specified at each location as the local base value which was kept constant for all the runs. Though different researchers [Samuel (1995)] have tried to formulate the stage wise variation of n in different ways, for the case illustrated here the local variation was assumed as

$$n(x, y) = n(x)\{1+(h / R)*0.15\}(1 / h)^{4/5}4.5 \quad (3)$$

where, n (x) is the local base value, h is the depth of flow above the thalweg point and R is the hydraulic radius. The notation n(x,y) refers to the variation of n(x) with the change of water level stage. From field investigation of Kinu river the vegetation condition suggests the variation pattern of n similar to those represented in Fig. 1. So, the equation (3) is assumed to be representative as Knight(1989) also presented similar discussion.

The joint probability plot of load and resistance for a certain location(section 49.5 km upstream of the Tone river confluence) of the whole reach is also presented in Fig. 2. Calculation of the volume below the surface bounded by the $Q_{Load} = Q_{Res}$ line determines the probability of failure at that location.

CONCLUSION:

Similar approach can be applied for evaluating risk of flooding at the different cross sections of the whole reach. Manning's n at each location can be considered as a combination of wide variation.

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