Erosion of River Bank due to Overflow

by

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Primitive experiments about the erosion of river banks due to overflow are carried out by using several types of model banks with different kinds of soil and slope gradient. And the effects of soil composition, overflow discharge and slope gradient on the process of the bank erosion are discussed.

1. Introduction

Most of the river banks are made of cohesive soil and designed to fulfill the stability condition of soil mechanics, and the condition against the erosion due to the flow over the bank is not taken into consideration in designing. It is reported that about 80 percent of bank failure is caused by the overflow[1]. If the bank is not destroyed completely even by the overflow, the damage by the flood will not become serious. And if it takes long time for the bank to be destroyed by the overflow, people will have enough time to escape from the flood or to fight with the flood. The river bank is basically designed not to be overflowed, and design flood discharge and bank height have been discussed sufficiently from the view point of hydrology and hydraulics. But soil mechanical and hydraulic discussion about the strength of bank slope against the overflow has been insufficient and only few experimental researches were done by Institute of Public Works of Ministry of Construction[2),3)].

In this paper, the process of the bank failure due to overflow is discussed experimentally by small scale bank models with several kinds of soil and slope gradient.

2. Summary of experiments

Model banks with the height of 25cm and the topwidth of 20cm were molded and settled on the middle of a flume of 10cm of width and 30cm in depth as shown in Fig.1. The water content of the soil for the model bank was adjusted to be optimum. After hardenning the soil by a square timber with a section of 5cm x 5cm, the soil was cut into a model bank. The test core of the soil was also taken from the bank and dry density and shearing strength were measured. Experimental conditions are shown in Table 1, in which ρ_d and C are dry density and cohesion of the bank soil, respectively, and q and h_c are

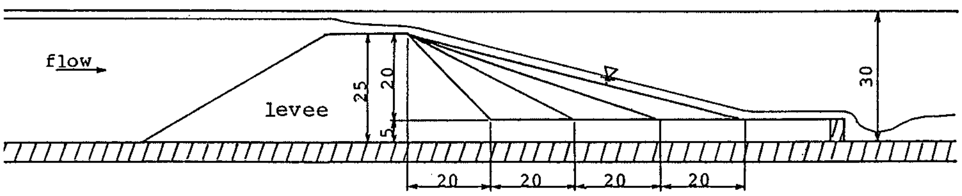

Fig.1 Experimental flume and model bank.

Table 1 Experimental conditions.

Run No.	soil			flow	
	Clay (%)	ρ_d (g/cm^3)	C (N/cm^2)	q (cm^2/s)	h_c (cm)
1	100	1.40	10.19	84.6	1.94
2				112.1	2.34
3				138.9	2.70
4				160.2	2.97
5				193.7	3.37
6	75	1.67	8.82	84.6	1.94
7				112.1	2.34
8				138.9	2.70
9				160.2	2.97
10				193.7	3.37
11	50	1.71	5.10	84.6	1.94
12				112.1	2.34
13				138.9	2.70
14				160.2	2.97
15				193.7	3.37
16	25	1.72	2.55	84.6	1.94
17				112.1	2.34
18				138.9	2.70
19				160.2	2.97
20				193.7	3.37

Bank Slope 1:2

Run No.	soil			Bank Slope
	Clay (%)	ρ_d (g/cm^3)	C (N/cm^2)	
21	100	1.40	10.19	1 : 1
22				1 : 2
23				1 : 3
24				1 : 4
25	75	1.67	8.82	1 : 1
26				1 : 2
27				1 : 3
28				1 : 4
29	50	1.72	5.10	1 : 1
30				1 : 2
31				1 : 3
32				1 : 4
33	25	1.82	2.55	1 : 1
34				1 : 2
35				1 : 3
36				1 : 4

$q = 138.9$ cm^2/s , $h_c = 2.70$ cm

discharge per unit width and critical flow depth of the overflow water, respectively. Run 1~Run 20 are for banks with slope gradient of 1:2 and with different soil composition and overflow depth. Run 21~Run 36 are for banks with different slope gradient of 1:1, 1:2, 1:3 and 1:4, and with the same overflow discharge of 138.9cm^2/s. The experimental conditions mentioned above are expected to offer the basic data with which one can discuss about the effect of soil composition, overflow discharge and slope gradient on the process of the bank erosion. Four kinds of soil are used and their grain size accumulation curves are shown in Fig.2. The soils of the model banks were made by mixing clay((a) in Fig.2) obtained at Fujinomori in Uji City with sand((b) in Fig.2) with mean diameter of 0.6mm. The erosion peocess of the model bank was recorded by a video camera through a transparent sidewall of the flume, and the shape of the eroded bank was analyzed with the aid of a video-moniter and video-position analyzer.

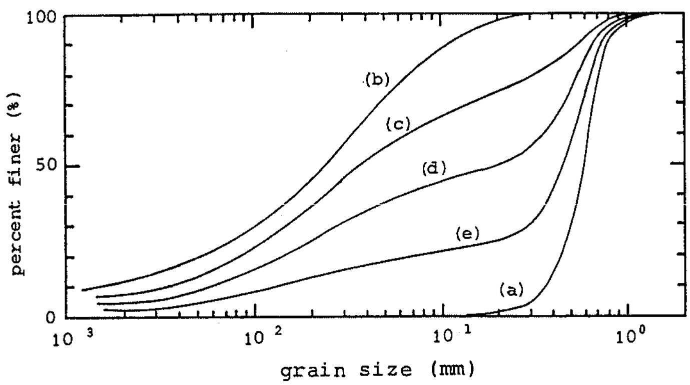

Fig.2 Grain size accumulation curves of the soil of model bank.

3. Effect of soil composition

Fig.3 shows an example of scouring process of river banks due to overflow, in which figure(a) indicates bank profiles at every five minutes after the commencement of the overflow for Run 5(clay 100%) and figure(b) indicates

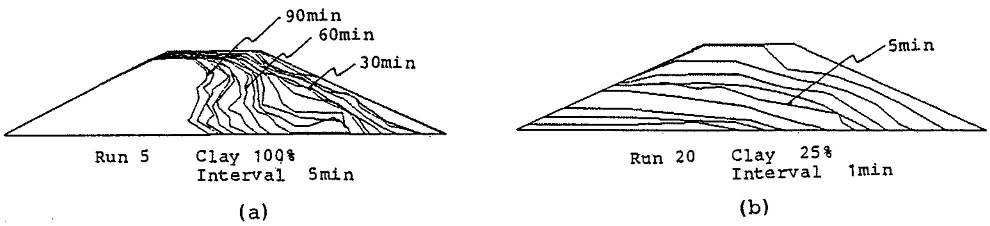

Fig.3 Typical scouring process of river bank due to overflow.

bank profiles at every one minute for Run 20 (clay 25%, sand 75%). It can be seen that the eroding rate of a bank made of clay is much smaller than a bank which contains a lot of sand and eroded bank shapes are quite different between these two banks: the sandy bank is scoured almost uniformly along the slope surface, whereas the slope of the clay bank is scoured so as to become steeper and sudden falls of the slope occur.

Fig. 4 shows the time variation of eroded soil volume V of the bank with slope gradient of 1:2, being grouped according to the same overflow discharge and different soil. It seems that the eroded soil volume V is almost linear to the elasped time t althouth the eroding rate of the bank depends strongly on the soil composition: clay banks are much stronger than sandy banks with less clay. But there is not any difference in the scouring properties between banks of 100% clay and 75% caly. An index which indicates the strength of

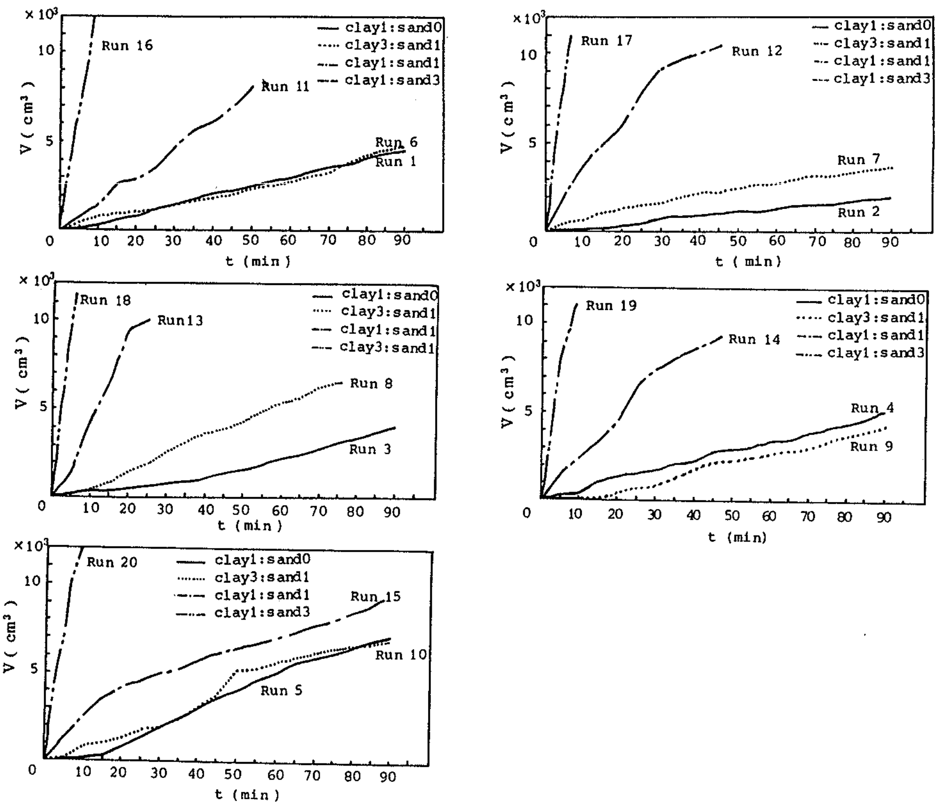

Fig. 4 Time variation of eroded soil volume (for the same overflow discharge and different soil).

bank surface registance against erosion by the overflow should express the surface condition of the soil which is adjacent to the overflow water. Although such kind of index is not established so far, cohesion C may be one of such indeces. Fig.5 shows the relationship between cohesion C of the bank soil and half-volume time $T_{1/2}$ which is the elasped time when the half of the initial total bank valume is eroded. As C becomes large $T_{1/2}$ becomes large sharply, which means that the more a bank contains clay, the less it is erosive. The strength of the bank against overflow depends on the soil composition much more thanthe overflow discharge.

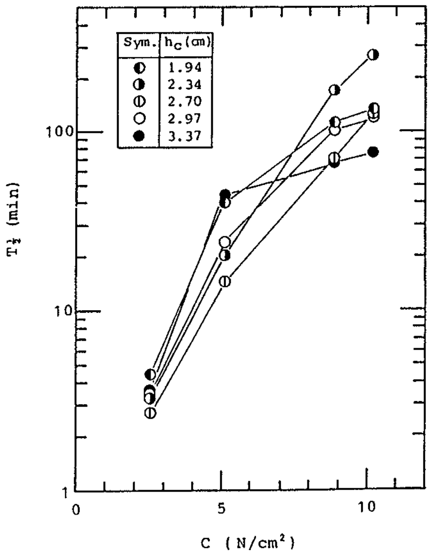

Fig.5 Relationship between C and $T_{1/2}$.

4. Effect of overflow discharge

Fig.6 shows the time variation of eroded soil volume V of the bank with the slope gradient of 1:2, being grouped according to the same soil and different overflow discharges, which makes it clear the effect of overflow discharge on the erosion properties. Expected property such that the erosinq rate becomes large as the overflow discharge increases is not shown clearly. But if one draw the relationship between overflow discharge q and endurance time T_B, the effect of the overflow discharge becomes clear. Here the endurance time T_B is defined as the elasped time when the upstream shoulder of the bank is eroded by 10 percent of the initial bank height. It seems to be more reasonable to use T_B rather than $T_{1/2}$ from the view point of perfect failure of bank, because the eroded shapes are quite different between sandy and clay banks as shown in Fig.7(sandy bank: AD, caly bank: BC in Fig.7). According to the relationship between q and T_B as shown in Fig.8, T_B seems to decrease slightly as q inceases, and $q \cdot T_B$ which is the total discharge until the upstream shoulder is eroded by 10 percent of the bank height is constant for the same soil. Although the constant value depends on the soil composition, there is a tendency that the total overflow volume reaches a constant value when the bank failure occurs. This means that the erosion rate of the bank depends on the overflow discharge as well, though it is not so effective as the soil composition.

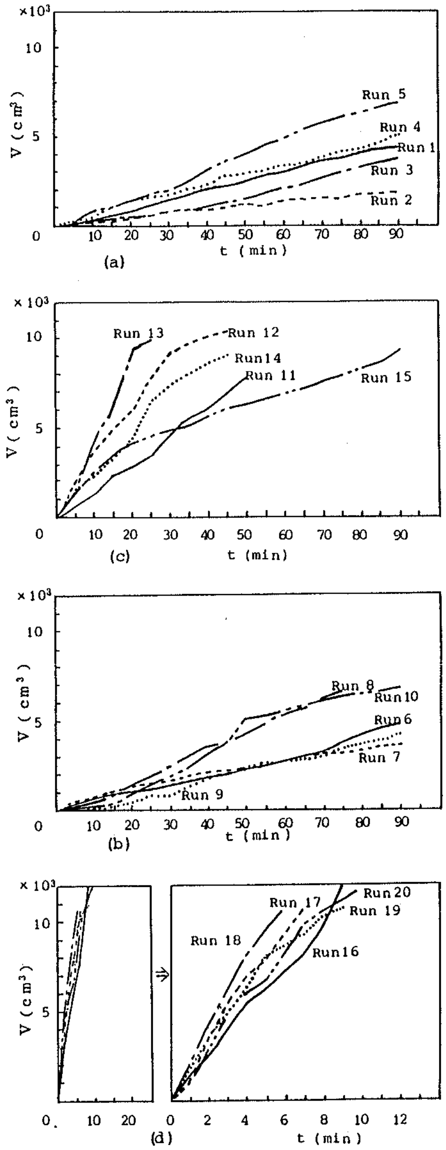

Fig.6 Time variation of eroded soil volume(for the same soil and different overflow discharge).

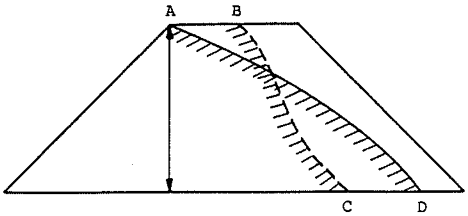

Fig.7 Types of eroded bank shape.

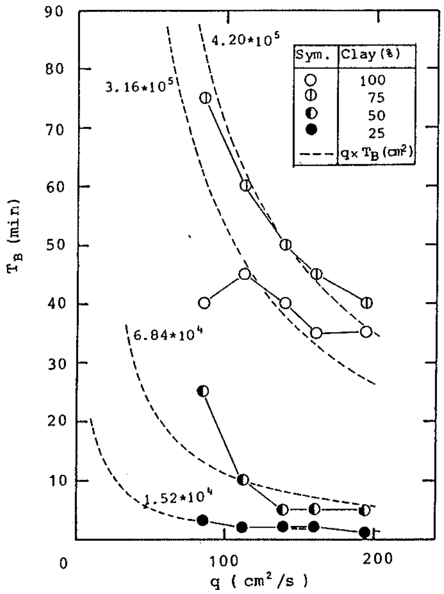

Fig.8 Releationship between q and T_B.

5. Effect of slope gradient

Fig.9 shows the time variation of eroded soil volume V of banks with different slope gradient under the constant overflow discharge, being grouped according to the same soil, which indicates the effect of the slope gradient on the erosing rate of the bank. Although the erosing rate seems not to depend on the slope gradient in the case of clay bank, the erosing rate of sandy bank depends on the slope gradient. For example, in the case of the bank which contains clay of only 25%, the erosing rate of the bank with the slope gradient of 1:4 is less than half of that of 1:2.

Fig.10 shows the relationship between cohesion C of the bank soil and half-volume time $T_{1/2}$ for banks with different slope gradients. It can be seen that the erosing rate of the bank with the mildest slope(gradient of 1:4) is comparatively small, especially for sandy bank with clay of 25 percent, but there is not significant difference of the erosing rate among banks with other three gradients.

Fig.11 shows the relationship between C and the endurance time T_B for banks with different slope gradients. The erosing rate of sandy bank with clay of only 25 percent becomes large with increase of the slope gradient, but in the case of clay bank the erosing rate does not depend on the slope gradient.

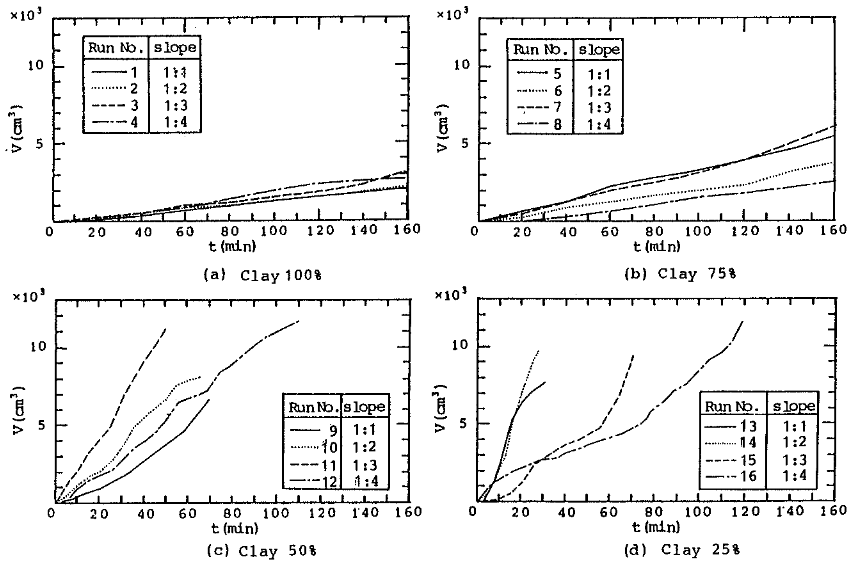

Fig.9 Time variation of eroded soil volume(for the constant overflow discharge and different slope).

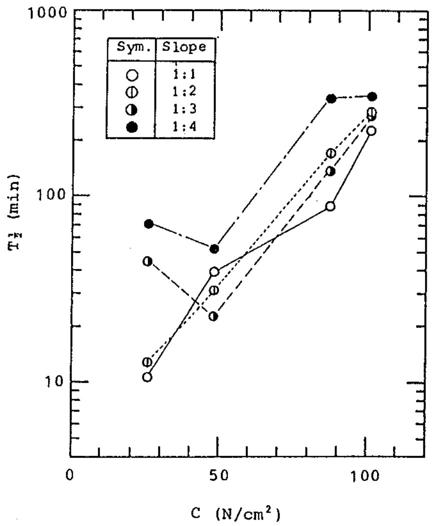

Fig.10 Relationship between C and $T_{1/2}$.

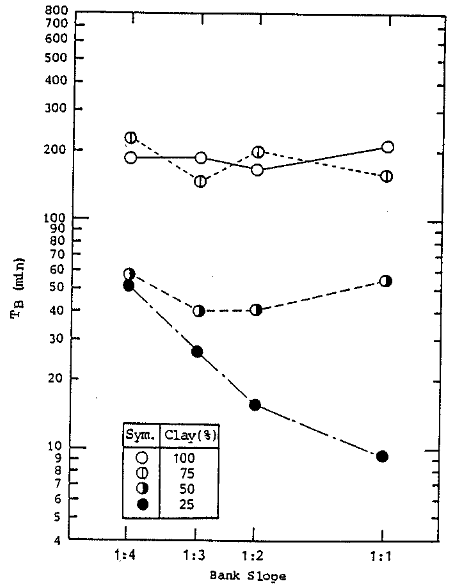

Fig.11 Relationship between C and T_B.

6. Conclusion

Through the primitive experiments about the bank failure due to overflow, the following results were obtained;

1) The sandy bank is scoured almost uniformly along the slope surface, whereas the slope of the clay bank is scoured so as to become steeper and sudden falls of the slope occur.
2) clay banks are much stronger than sandy banks with less caly. But the bank with 75% clay is almost as strong as the bank of 100% clay.
3) There is a tendency that the total overflow volume reaches a constant value when the bank failure occurs for the same soil, although the constant values depend on the soil composition.
4) The erosion rate of sandy bank of 25% clay becomes large as the slope gradient increases, but for the bank of more clay the effect of the slope gradient on the erosion rate is small.

In this paper, the outline of the river bank failure was discussed qualitatively only. But these qualitatve results obtained here will become the base of the further analytical study.

References

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