

Study on the Vibration Characteristics of Filldam with a Rigid Core – II. Experimental Study –

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Abstract

In this paper, the vibration characteristics are described from the results obtained experimentally by using relatively small shaking table and also failure patterns are shown from failure tests. And from these results, it is cleared that the possibility of construction of filldams with a rather rigid core is possible if some design problems are discussed enoughly.

I. Introduction

We reported of the vibration characteristics of filldams by analytical method and so here, we show the experimental results of filldams models as to the vibration and the failure pattern of filldams by failure tests.

Recently, it is apt to take a bigger model in order to investigate the earthquake response of the real filldams by using a big shaking table, however it may be sometimes too expensive and so we tried to take the small shaking table in order to investigate the qualitative characteristics of the vibration of filldams with some rigid core and also whether it can be realized to construct the rigid type core dams, or not, from the view point of vibration and statical states.

II. Experimental Method

1. Test models of filldams

We have basically 3 cases of dam models, which are as follows;

(A) : a homogenous model

(B) : a core type model having rigid property as same as concrete

(C) : a core type model having clay as likely as Kaoline

Fig. 1 shows the models to be tested.

In this figure, (•) sign shows the location of acceleration sensor attached in the dam models. Table 1 shows the study cases of dams by using the shaking table which is controled by frequency and amplitude of vibration source.

In making such models on the shaking table, we use materials as shown in Table 2.

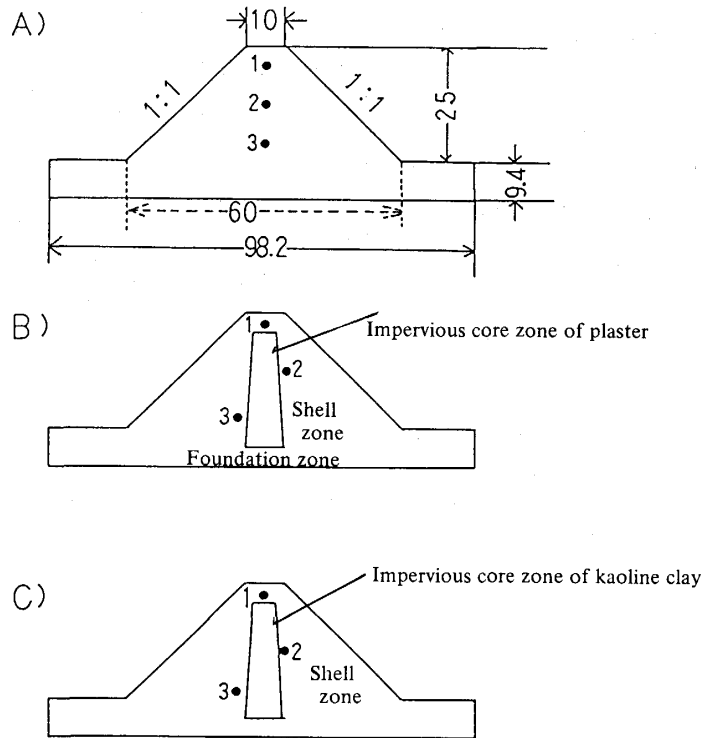


Fig. 1 Experimental models with foundation
 A) Homogeneous model
 B), C) Central core type model

Table 1 Classification of experiment

Water content (%)		Dam models			
		1.0	1.5	2.0	2.5
A	Isotropic type	○	○	○	○
B	Central core type	○	○	○	○
C	a	○	/	/	/
	b	○	○	○	/
	c	○	/	/	/

Table 2 Material constants of dam model for analyses

Material constant Material name	Dry density γ_d (g/cm ³)	Water content w (%)	Angle of internal friction ϕ (°)	Cohesion C (kg/cm ²)
S-1.0	1.465	1.0	30.08	0.055
S-1.5	1.445	1.5	33.31	0.144
S-2.0	1.450	2.0	36.69	0.049
S-2.5	1.436	2.5	35.55	0.105
K-a	1.622	27.0	24.65	0.506
K-b	1.744	27.0	23.67	0.793
K-c	1.770	27.0	34.68	0.675
P	1.285	/	34.93	33.50

- where, S : Standard Sand
 K : Kaoline clay
 a : 30 times compaction for total 4 layers
 b : 60 times compaction for total 4 layers
 c : 90 times compaction for total 4 layers

And we make the models carefully by compacting sand in some conditions, which mean changing water contents and compaction numbers and made shapes of dams with the scale.

Fig. 2 shows the input acceleration wave form to be subjected to the models and also shows the period time to be analyzed, which means stational states of vibration.

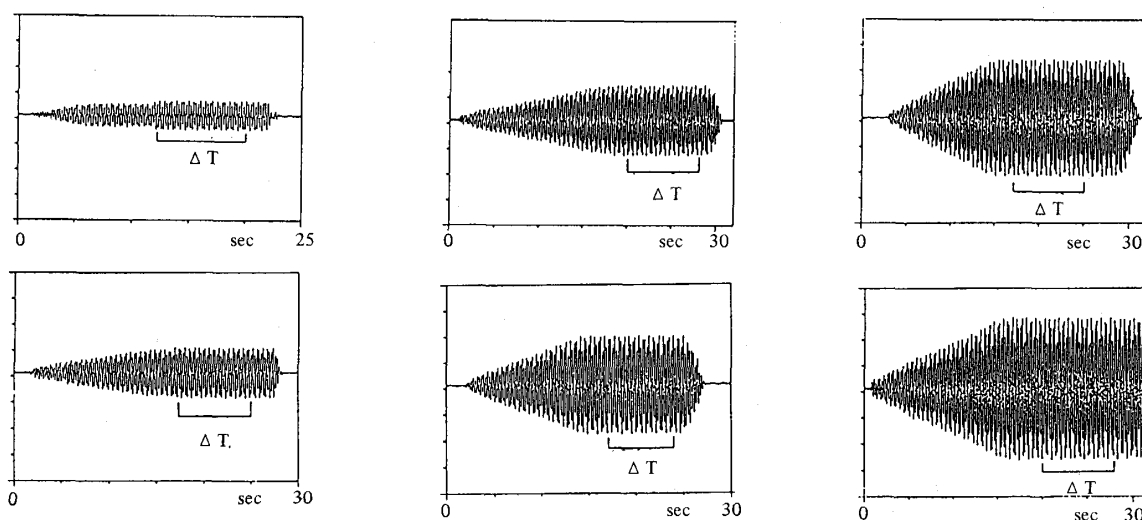


Fig. 2 Input acceleration wave form to be subjected models and period time (ΔT) to be analyzed.

III. Results and Consideration

Fig. 3 ~ Fig. 5 show the distribution of response acceleration at each point and for each strength of acceleration. Fig. 3 is to the case A according to the change of water contents. When the water content is 1.5 %, the distribution of acceleration is so different from others, especially at higher input acceleration, because some failure may be coming at that state, but other distributions are not so different from each other.

Fig. 4 is to the case B as same as previous case. In this case, except water content 2.5 %, almost same distribution can be seen, which is not so wide. Because it can be said that rigid core may restrict the behavior of earth material to be surrounded. When the water content is 2.5 %, and the state of acceleration is higher, the distribution is changed because of some failure.

Fig. 5 is to the case of C_b , which shows almost same results at each water content.

Fig. 6 shows the comparison with each case when the water content is 1.0 %. From this figure, it can be said that when the strength of acceleration is low, response acceleration is almost same at each point, but the greater the strength of acceleration becomes, the bigger the difference between the response and the input earthquake, but the case of A is the most small value at near the top of the core. This depends on the damping effect of earth materials.

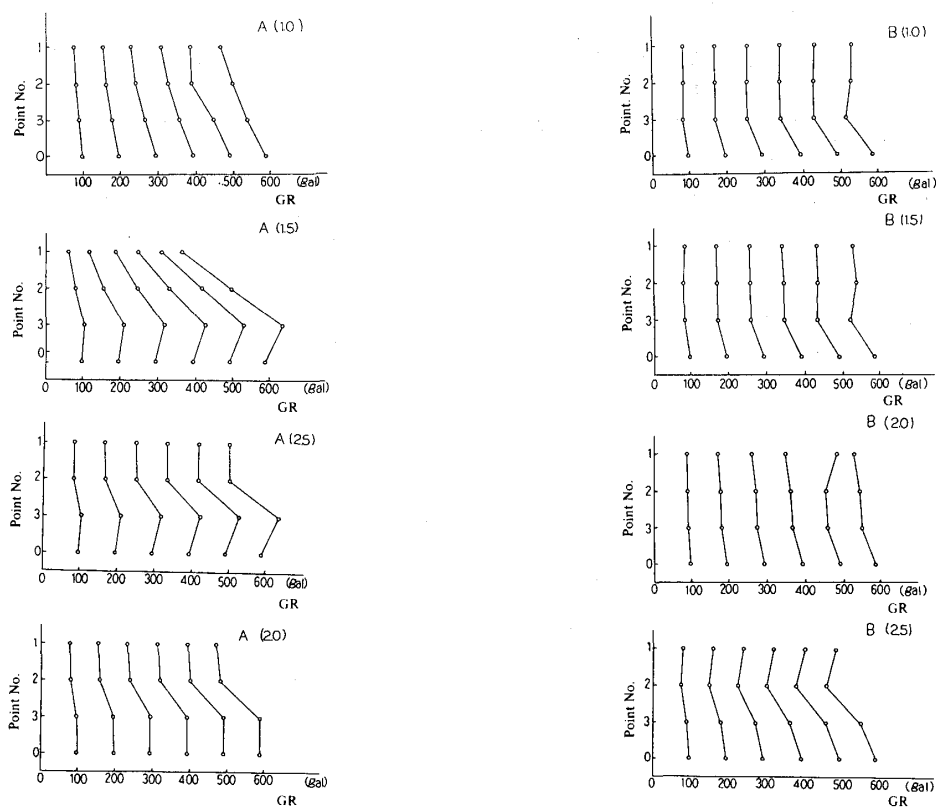


Fig. 3 Distribution of response acceleration (GR) at each point of dam model (A type)

Fig. 4 Distribution of response acceleration (GR) at each point of dam model (B type)

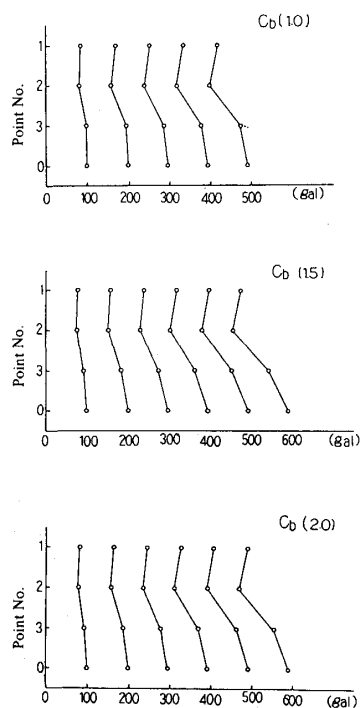


Fig. 5 Distribution of response acceleration (GR) at each point of dam model (C_b type) for each water content (1.0, 1.5 and 2.0 %)

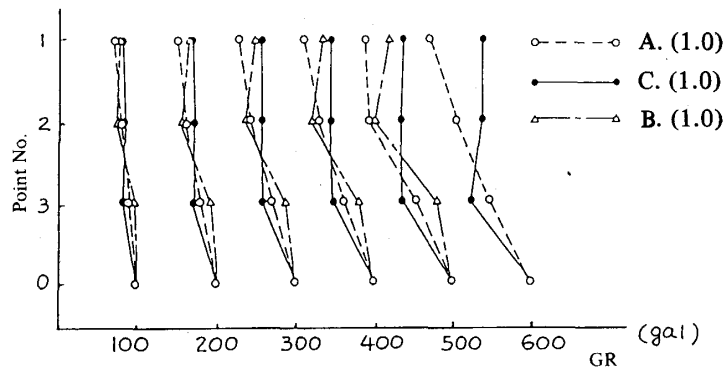


Fig. 6 Distribution of response acceleration (GR) at each case (A, C and B type at the same water content of 1.0 %)

However, as some failure for vibration comes to dams, the response acceleration may be smaller.

Nextly, we took the failure tests by vibration according to making input acceleration higher and we observed the failure of each dam as shown previously.

Fig. 7 shows the sliding line and the shape of dam after failure. From these figures, it can be seen that there are many patterns of failure for every conditions. And we can show the representative failure pattern to be seen generally for filldams as shown in Fig.8.

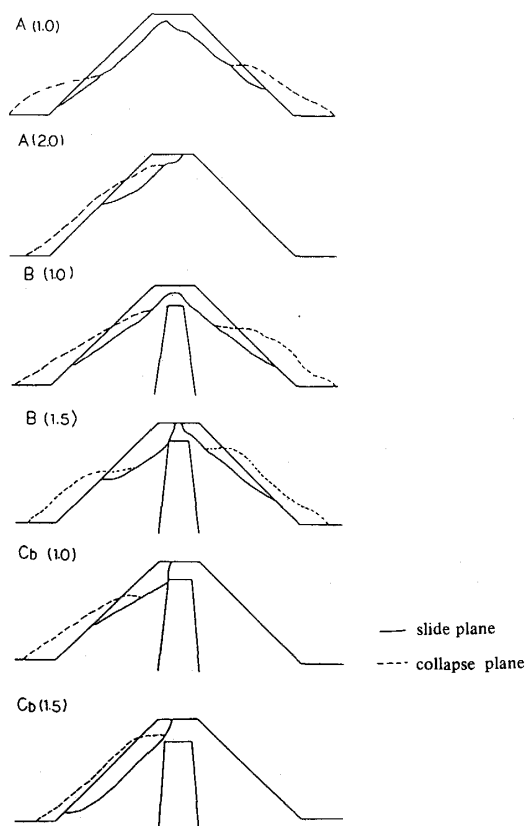


Fig. 7 Sliding line and shape of dam model after dynamic failure. (A, B and C type models)

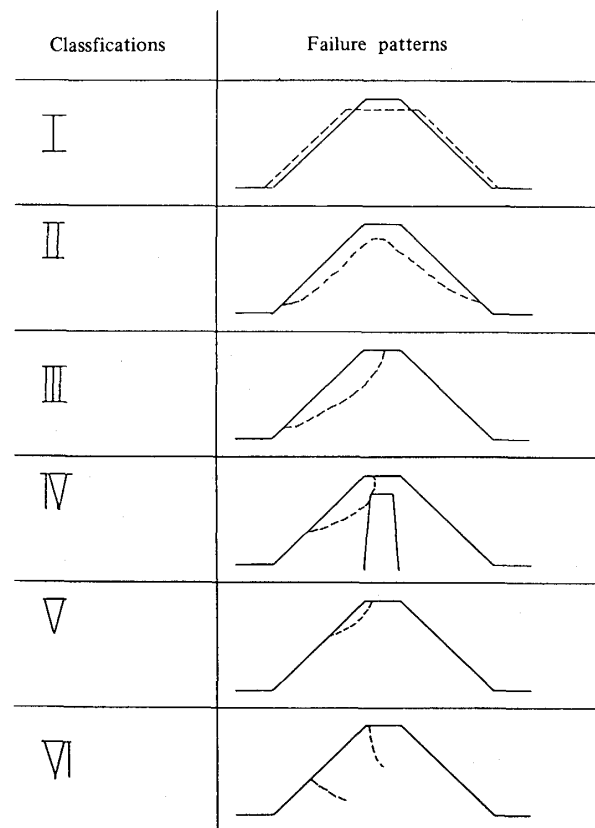


Fig. 8 Representative failure patterns of filldams.

The characteristics of each pattern can be presented as follows;

- Type I : Keeping basical shape of dam, total body of dam sinks uniformly. It can be seen in the higher water content.
- Type II : Without keeping the shape of dam, both sliding sides come to be appeared. It can be seen in the lower water content.
- Type III : Cracks which appear at the top of dam become bigger and the one side slope start to slide to failure.
- Type IV : Cracks on the top become bigger especially at the boundary between the core and shell and failure to slide.
- Type V : Failure comes mainly at near surface of slope and failure to slide.
- Type VI : Cracks come to be appeared locatly and some settlement comes to be appeared.

And also, we observed the relationship between the settlement at each state and input acceleration for each case. Fig. 9 shows the relationship for each case and also shows the state of which crack coming into the dam.

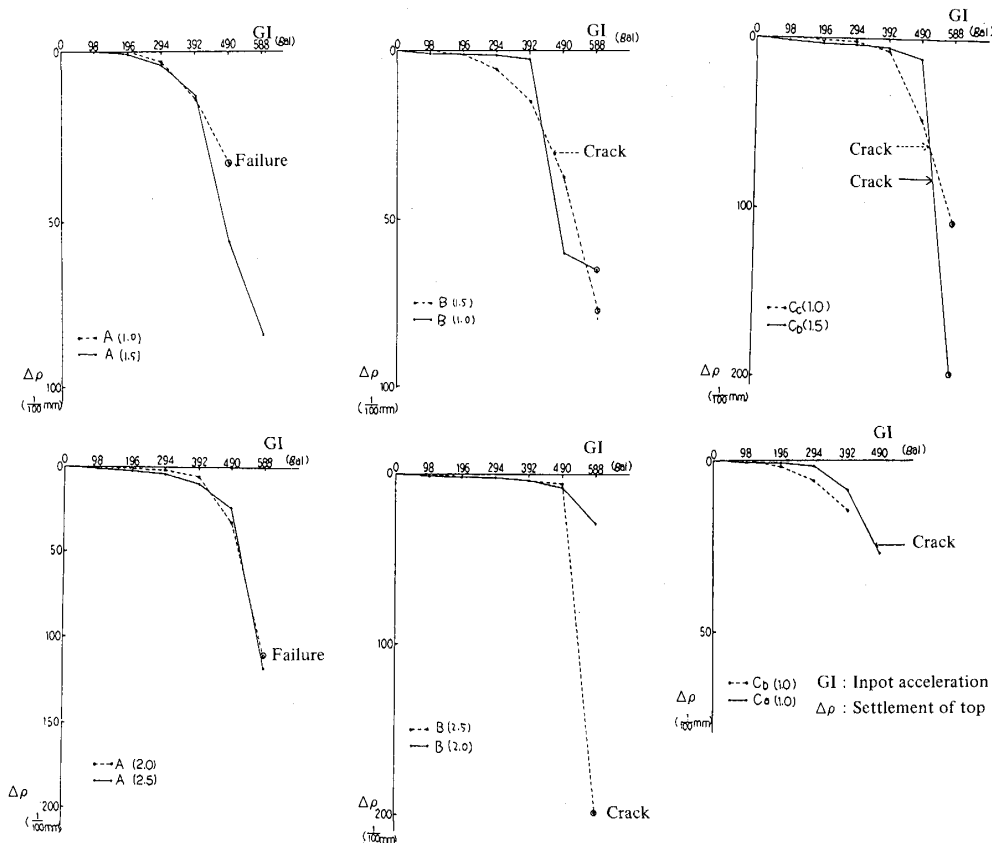


Fig. 9 The relationship between the settlement ($\Delta\rho$) at each state and input acceleration (GI) for each case.

From these figures, it can be said that filldams with a core are apt to failure at suddenly when the strength of acceleration reaches to some value which may be over about 400 gal or 500 gal.

This means that the core, which is rather rigid, can restrict for earth to move down and to failure even in dynamical states. This fact also may be said from Fig. 10 which shows the relationship between the settlement and the time at the acting state of maximum acceleration.

In this figure, the case of B which has rigid core keep the state relatively safe for about 3 minutes and other cases cannot keep the states so long.

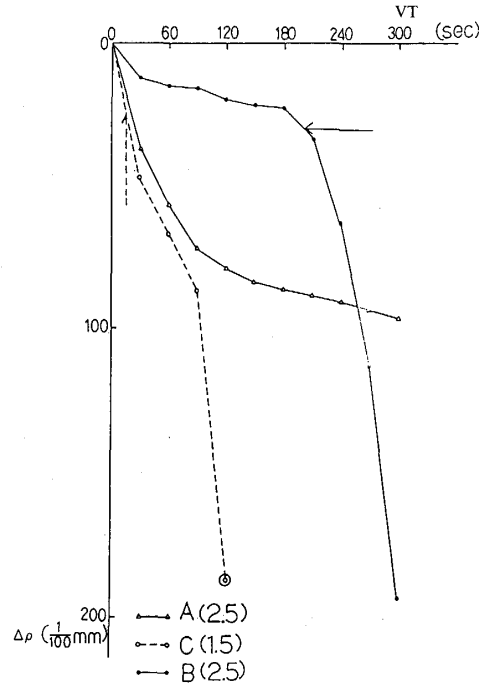


Fig. 10 The relationship between the settlement of top of experimental dam models ($\Delta\rho$) and the time (VT) during the vibration.

We tried to make it sure by using the theory of sliding circular. Fig. 11 and Fig. 12 show the analytical results obtained for the case of A and B.

In the case of A, a sliding circular plane starts at the shoulder of the top of dam, however, in the case of B the circular plane starts on the top of dam and cuts the core

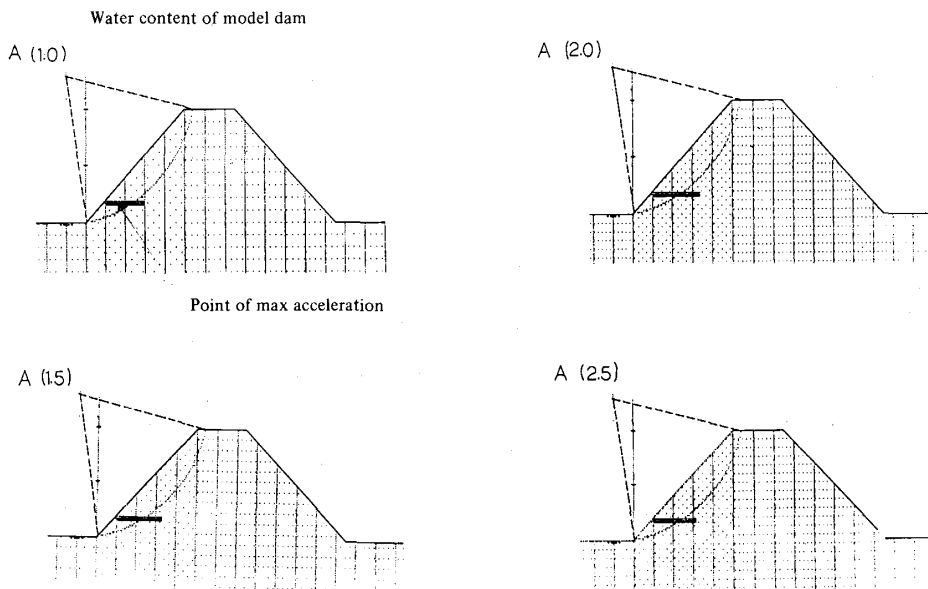


Fig. 11 Failure lines of experimental model dams (A type : Homogeneous type) by the theory of sliding circular.

zone. And also we obtained the safety factor for each case and show in the Fig. 13, which shows the relationship between the safety factor and the input strength of acceleration.

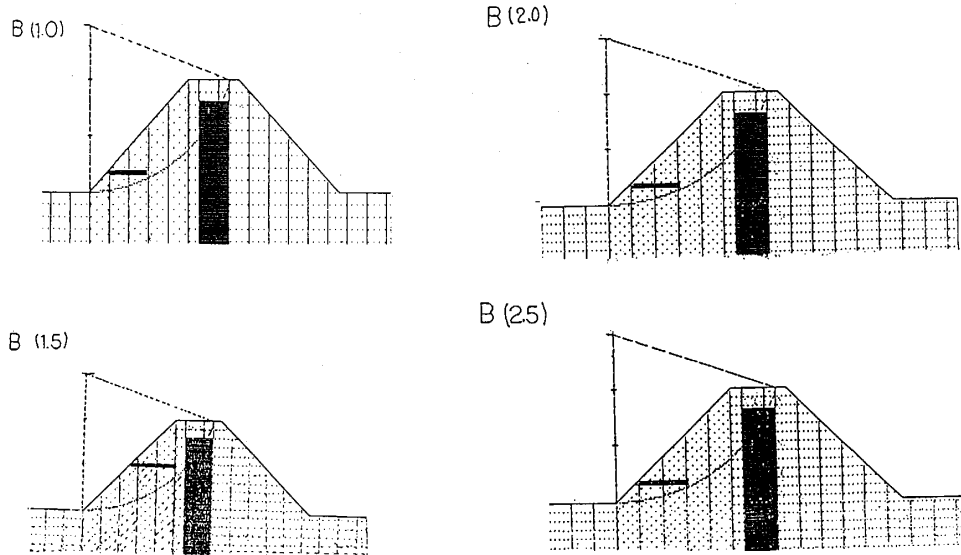


Fig. 12 Failure lines of experimental model dams (B type: Core type) by the theory of sliding circular.

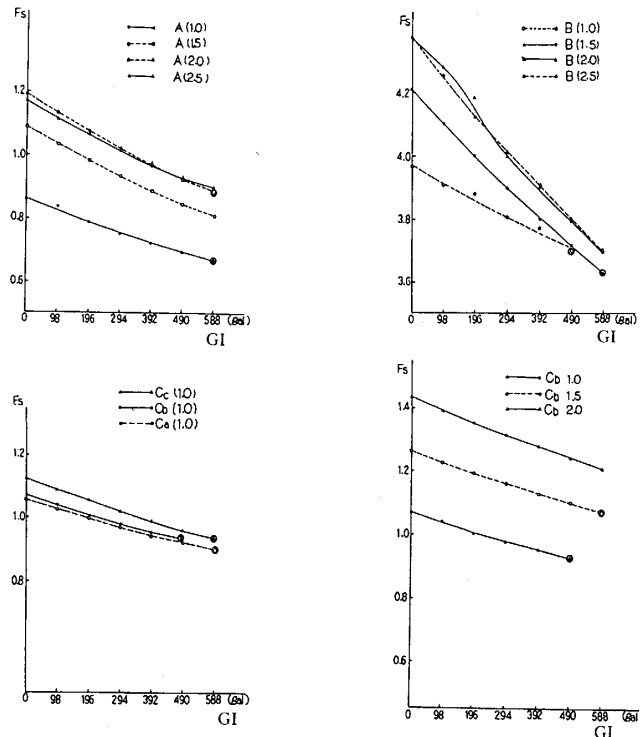


Fig. 13 Safety factors (SF) of experimental dam models (A, B and C types) vs. Input acceleration (GI) of shaking table.

From this figure, although safety factor may depend on the water contents, totally it can be said that the case of B which has the rigid core has the higher safety factor than in the others.

IV. Conclusion

From the results obtained by experimental study, it can be concluded as follows:

- (1) The distribution of acceleration becomes smaller at upper zone of dam model because it may be depending on large damping of sand.
- (2) At the low level of acceleration, the core type filldam stands safely, but over 400 gal, all cases of dam models was failed within about 3 minutes.
- (3) The vibration characteristics depends on the properties of materials.
- (4) Basical 6 failure patterns was found in the test of failure at stational state of vibration as shown in Fig. 8.
- (5) The rigid core type filldam may have an possibility to be constructed if conditions of the boundary between the core and earth materials are cleared to restrict sliding.

V. Reference

1. ARAKAWA N., et al (1983) : Vibration model test on the failure characteristics of embankment on sandy foundation at earthquake. Civil engineering report, 25-11. (*in Japanese*)
2. H. Bolton Seed, F. ASCE (1983): Earthquake-resistant Design of earth Dams. Proc. G. E. ASCE