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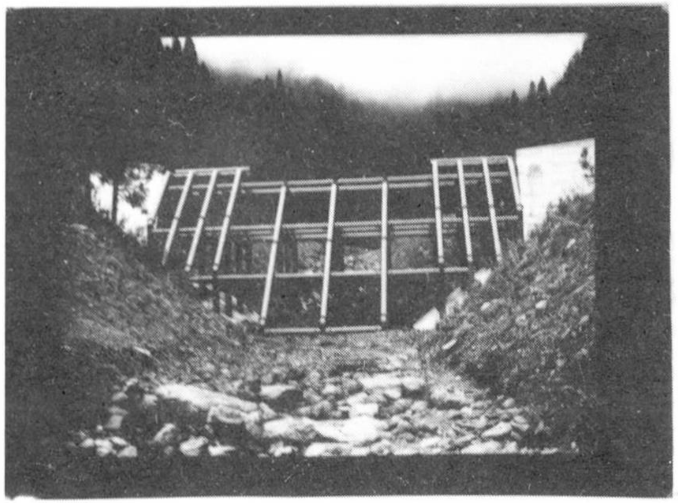

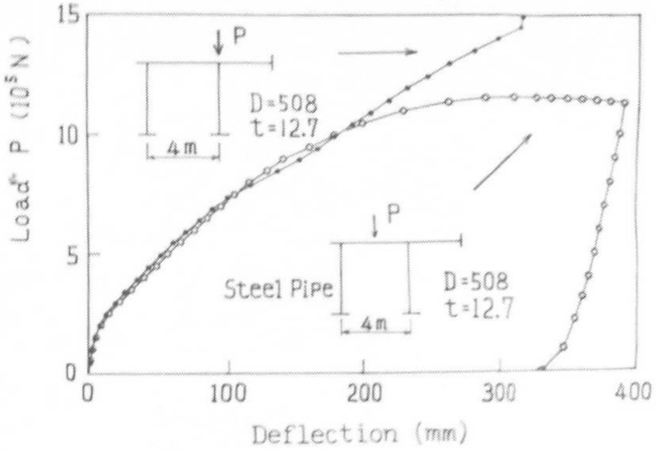

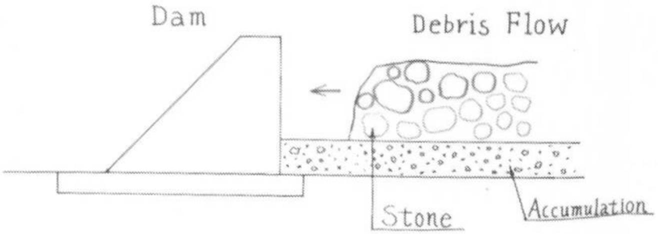

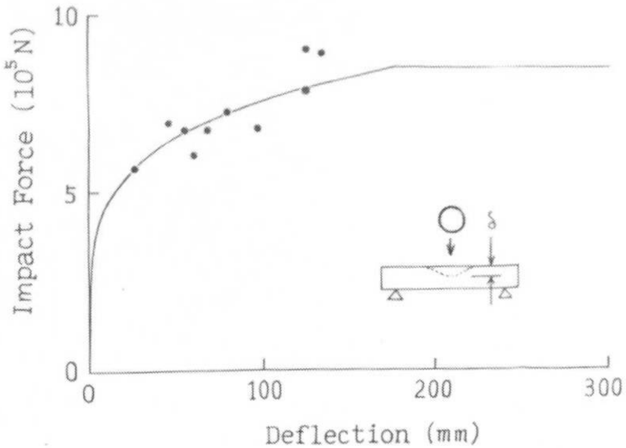

Design of Steel Pipe Grid Dam for Debris Flow Control

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1. DEBRIS FLOW CONTROL

Debris flow is one of the most serious types of natural desaster, and various studies on debris flow, on-site observation of debris flow, studies of prevention measures against the disaster and so on have been carried out up to this day. One of the countermeasures is prevention of occurence of debris flow in use of a group of small consolidation dams. And another countermeasure is control of the flowing condition of the debris flow in use of various types of dams.

A steel pipe grid dam is one of the control dams of the debris flow and consists of large-sized steel pipes latticed in a three-dimensional form, which aims at arresting hazardous running stones while at the same time adjusting the flow of sand and soil effectively.[1)]

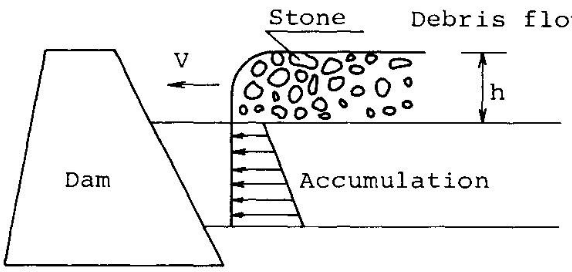

Fig.1 Debris flow

2. DESIGN OF STEEL PIPE GRID DAM

It is assumed that the dam is subjected to two kinds of loads which are stationary loads and impact forces.

(1) Soil pressure: Soil accumulates around the grid dam due to variation of a river bed, and the pressure acts on the grid dam.
(2) Fluid force: As if stones and gravels in the debris flow block up the grid of the dam, it is assumed that the fluid force of the debris flow acts on the dam all over.
(3) Inpact forces of stones: Huge stones are contained at the head of the debris flow as shown in Fig.1. The stones collide with the grid members of the dam and impact forces act on the member.

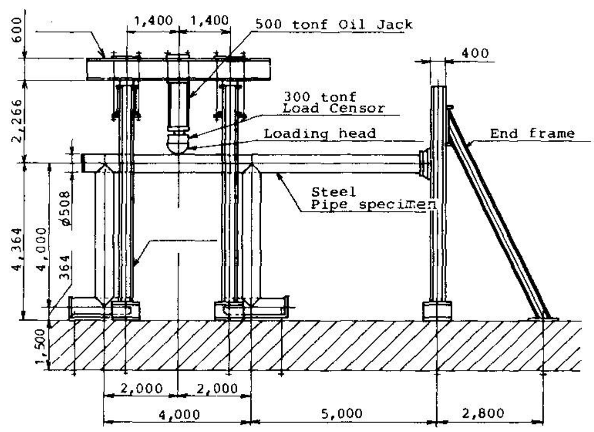

Fig.2 Loading test apparatus

The dam has to be stable against the soil and fluid pressures so as not to slide, roll over and collapse. While the dam has to be designed against the impact forces of stones so as not to lost the capacity of adjusting soil and sand discharge. It is considerably difficult to design it without a damage of the dam, because the more the dam is stiffened, the more the impact force increases. Therefore it is considered that the dam is allowed to have a local damage and that the kinematic energy of a stone is replaced to the strain energy of a grid member in inelastic deformation range.

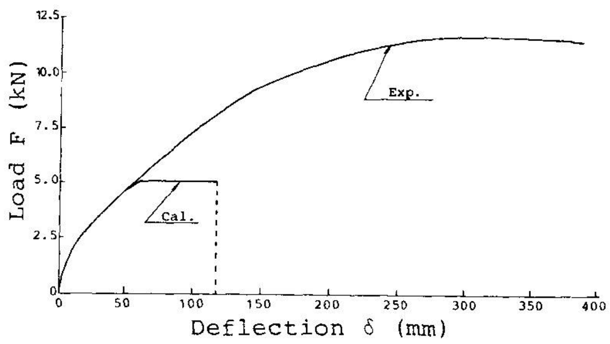

Fig.3 Load-deflection curve
Loading at the midpoint of joints

3. CAPACITY OF ENERGY ABSORPTION OF A GRID MEMBER

Static loading tests of F-shaped frames consisting of steel pipes of 508mm in diameter and 12.7mm in thickness have been carried out as shown in Fig.2. The yield stress of the pipe material was 381MPa from results of a test, although the value of the Japanese standard about its material is 235MPa.

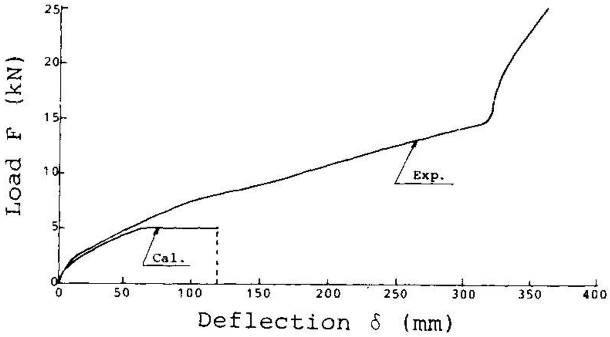

Fig.4 Load-deflection curve
Loading at a joint

The load-deflection relation in case of loading at a midpoint of joints of pipes is shown in Fig.3 and the similar relation in case of loading at a joint is shown in Fig.4. The deflections of the test results in Fig.3 and 4 are shown as sums of the local denting deformation of the pipe wall and the overall bending deformation of the pipe.

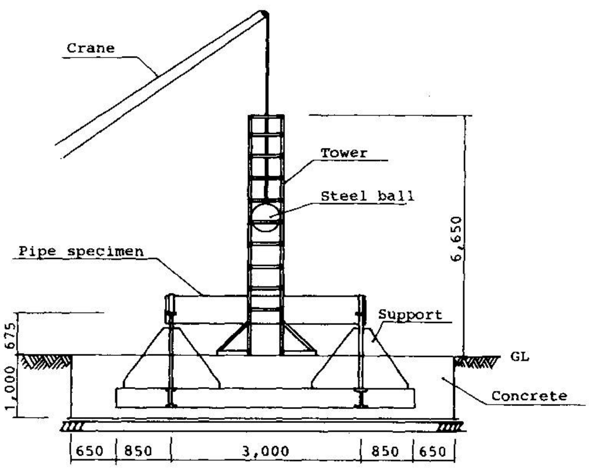

Fig.5 General view of impact tests

The local dent has appeared at the initial state of loading, and at the following state of loading the overall bending and some additional local denting have yielded.

Analytical treatment of these local denting and overall bending damage has been reported in Ref.(2). From the report the relationship between the load and the dent depth has been given by

$$F_d = \frac{1}{4}K\delta_Y t^2 \left(\frac{\delta_d}{D}\right)^{1/2} \quad (1)$$

where δ_d : dent depth, D: diameter of a pipe, t: thickness of the pipe wall, δ_Y : yield stress of the pipe material, K: constant given by 150

The energy absorption, Ed, due to the dent is easily developed as

$$E_d = \frac{1}{6}K\delta_Y t^2 \left(\frac{\delta_d^3}{D}\right)^{1/2} \quad (2)$$

In addition, the overall bending collapse load, F_o, has been presented for the dented pipe fixed at the both ends as

$$F_o = \frac{4}{L} D^2 t \delta_Y (\cos\beta - \beta) \qquad \beta = \left(\frac{\delta_d}{D}\right)^{1/2} \left\{ 1 - \sqrt{\frac{16}{9}\left(\frac{\delta_d}{t}\right)^2 + 1} + \frac{4}{3}\frac{\delta_d}{t} \right\} \tag{3}$$

where L is a span length between both ends. The energy absorption, E_o, due to the collapse deformation is shown as

$$E_o = F_o \delta_o \tag{4}$$

where δ_o is the ultimate deformation at the loading point of the pipe. δ_d is obtained by solving simultaneously Eq.(1) and (3).

Substituting the yield stress on the Japanese standard into δ_Y in Eq.(1) and (3), a load-deflection relation of the tested pipe is obtained as a dotted line shown in Fig.3 and 4.

The ultimate deformation, δ_o, varies with a axial force, D/t and so on. In general, the member subjected to the lateral loading is in tension under the large lateral deformation, and the lateral load thereby does not decrease in its state.

For the pipe less than 40 in D/t, δ_o is assumed with enough safety as

$$\delta_o = 20\delta_E = 20 \frac{L^2 \delta_Y}{12ED} \tag{5}$$

where δ_E is the bending deformation at a midpoint of a pipe which give a yield stress to the surface fibre of the pipe. In case of the tested pipe

$$\delta_d = 60\text{mm}$$

and the quantity of the energy absorption of the test result is larger than 3 times as much as the estimated value.

4. IMPACT TESTS

A general view of impact tests is shown in Fig.5. The diameter and thickness of the pipe specimen are the same size as the pipe used in the static loading tests. The pipe were set on the both supports located 3m in distance. And a steel ball about 20kN in weight is lifted up 1m to 5m in height from a upper surface of the pipe, and fall down on the pipe.

Results of the tests are shown in Fig.6. In this test the magnitudes of the impact forces were in dent deformation range. A dotted line in Fig.6 shows a load-dent relation estimated by Eq.(1) in use of the yield stress in the Japanese standard. It is known that the estimated energy absorption is fairly less than the value of test results.

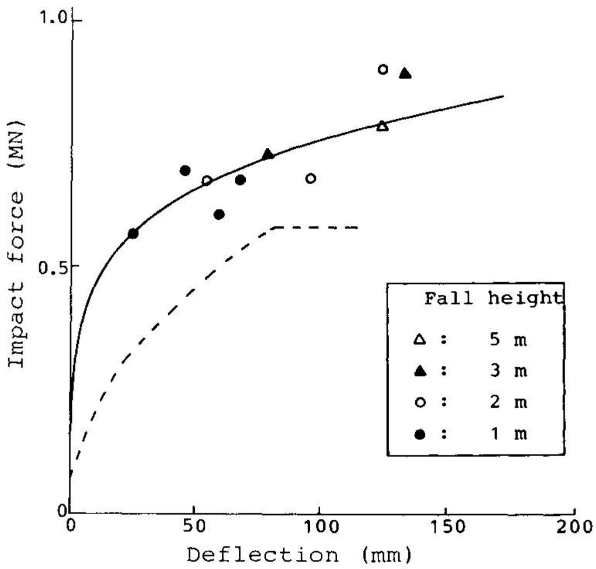

Fig.6 Impact force-deflection relation

Reference

(1) Namita, Y., korokuro-sawa Steel-pipe Grid Dam, Yamagata (Japan), IABSE STRUCTURES C-38/86, p58-59 IABSE PERIODICA, March 1986.

(2) Ellinas, C.P. and Walker, A.C.: Damage on Offshore Tublar Bracing Member, IABSE Colloquim, Ship Collision with Bridge and Offshore Structure, Copenhagen, 1983.